THE ARECANUT PALM

(*Areca catechu* Linn.)

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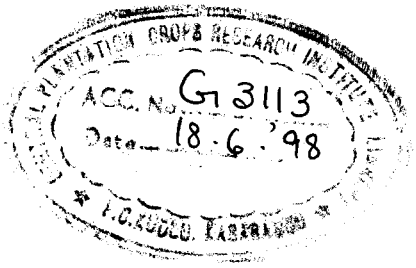

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FOREWORD

Arecanut is cultivated in about 1,84,500 ha in this country producing 1,91,400 tonnes of nut valued at Rs. 2500 million. More than four lakh people in different parts of the country, particularly those in the states of Karnataka, Kerala and Assam, are solely dependent on arecanut industry for their livelihood. Research on this crop was initiated towards the late fifties. Within a span of two decades, India has become self sufficient in arecanut. Main research support for this development came from the erstwhile Central Arecanut Research Station, Vittal (now the Regional Station of Central Plantation Crops Research Institute). The production of arecanut increased from 95,000 tonnes in 1961 to 1,91,400 tonnes in 1981.

Arecanut is one of the very few examples where research effort by way of improved varieties and associated technology has been adopted widely and the cultivation and production pattern of arecanut has substantially changed. Development and release of variety MANGALA *has been a major achievement. Also, introduction of cocoa as intercrop in arecanut garden has helped to revolutionise the economics of farming on arecanut lands significantly. There was even an over-production and a policy of restricting the area under this crop had to be advocated since the export potential for arecanut is rather limited. Research is being now diversified towards developing alternative uses for the crop.*

I am happy that the Silver Jubilee of Arecanut Research in India is being celebrated this year. The scientists concerned with arecanut research could take legitimate pride in their achievements and it is appropriate that a Monograph on Arecanut has been brought out for the occasion. The book clearly brings out how well planned research, effective extension and marketing system could contribute substantially to production and productivity and sustain high returns to the farmers.

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New Delhi,
October 13, 1982

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1
INTRODUCTION

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The arecanut palm, *Areca catechu* L. is the source of the common masticatory nut, popularly known as arecanut, betelnut or *supari*. It is extensively used in India by all sections of the people as a masticatory, and is an essential requisite for several religious and social ceremonies. Consequently, the arecanut palm occupies a prominent place among the cultivated crops in the states of Kerala, Karnataka, Assam, Meghalaya, Tamil Nadu and West Bengal and is of considerable economic and socio-religious importance for the entire country.

I. Antiquity of the arecanut

Innumerable references are found in several of the ancient Sanskrit texts to the arecanut palm, the arecanut and its uses. Bhat and Rao (1962) have produced evidences to prove the antiquity from a number of such works, among the most important one quoted being, *Anjana Charitra* by Sisu Mayana (B. C. 1300), where reference had been made to groups of arecanut palms full of inflorescences and branches presenting a nice appearance. In *Sisupala Vadha* by the famous Sanskrit poet, Magha (650 B.C., but according to some, not later than ninth century B.C.) mention is made of the soldiers of Sri Krishna from Dwaraka, who on landing in a marshy place came across a mixed garden of coconut and arecanut, and drank coconut water and chewed ripe arecanuts. *Raghuvamsa* by Kalidasa (fourth century A.D.) refers to the arecanut palms acting as support to the betel vine, and also to Sri Rama telling his consort, Sita Devi, of the rich and artistically laid out and abundantly bearing arecanut plantations on the West Coast of India. Finally, *Amara Kosha* by Amara Simha (sixth century A.D.) contains a number of synonyms of the arecanut indicating the popularity of the nut during that period. Ajanta Caves in Central India (dating from the second century B.C. to the ninth century A.D.) contain extremely artistic delineations of the arecanut palm; the palms have been given considerable importance in that, in one case (Cave No. 17, late fifth

century A.D.) they are set in a palace garden and in another, the Padmapani Cave (middle of the sixth century A. D.), the palm provides a backdrop to Padmapani (Frontispiece). According to Furtado (1960), one of the earliest references to the arecanut is in a letter written by the king of Cochin (in Kerala) in 1510 to one Alphonso de Albuquerque recommending to him to send ships to Coromandal and to the Moluccas to carry arecanut.

II. Origin and distribution of the arecanut palm

Considerable speculation surrounds the origin of the arecanut palm. There seems to be no record of fossil remains of the genus *Areca,* but the abundance of the palm genera discovered in the form of shells, leaves and stems from the Tertiary period probably indicates that this genus was in existence as far back as that period. According to Watt (1889), it is a native of Cochin China, Malay peninsula and neighbouring islands and according to Thomas Green (1823, quoted by Gode, 1961), arecanut is a native of the East Indies (present Indonesia) and Cochin China.

According to Blume (1836), the habitat of the arecanut palm is the Malay peninsula, Thailand and the neighbouring islands. De Candolle (1886) in his classical work, *The Origin of Cultivated Plants* stated that the country of origin is uncertain and probably Sunda Islands. Beccari (1919) described four cultivars of *A. catechu* and nine other species from the Philippines. From the many allied species including *A. catechu* var. *silvatica* existing in the Philippines, where *A. catechu* tends to produce many varieties, and also from the absence of similar allied species in other parts of the world, Beccari (1919) was inclined to think that it was in the Philippines that *A. catechu* finally assumed the specific characters.

Arecanuts have been reported from Indonesia (Petelot, Frontou and Carton, 1926), India and Sri Lanka (Blatter, 1926), Southern China (Hsiao-Liang, 1936), Taiwan (Yama Moto, 1939) and Java (Meijer, 1946). Blatter (1926) agreed with Martius (1832–1850) and De Candolle (1886) in stating that the exact native country of the betelnut palm is uncertain, as the tree has been extensively cultivated from time immemorial in all parts of the East Indies. Furtado (1933) stated that the theories as to original habitat of *Areca* may be misleading if based on uncertain reports unless it could be proved beyond doubt. An investigation of the range of distribution in a given locality where the plant is thought to be wild may perhaps throw further light on the origin, but he was certain that the original home of *Areca* is not in America.

Fisher (cited by Blatter, 1926) found the plants fruiting in wild state in the virgin forests of Attappadi ranges in Kerala at an altitude of about

1000 m. Raghavan (1957) indicated that since majority of the species of *Areca* have been reported from Malay Archipelago, the Philippines and other East Indies islands, the centre of origin of *A. catechu* is likely to be around the region. Bavappa (1963) studying the distribution pattern of *Areca* species, observed that the contiguous areas of Malaya, Borneo and Celebes having a maximum of 24 species could well be the area where the greatest diversity and wealth of forms of *Areca* are concentrated. Thus the East Indies group of islands may be taken as the centre of maximum variation.

III. Its several uses

1. Masticatory and socio-religious uses

The practice of chewing the arecanut, either alone or in combination with betel leaves or *pan* (*Piper betle* L.), lime, tobacco, camphor or spices, the combination then being called *tambula* has been in existence from time immemorial. Chewing is said to increase the production of saliva and gastric juices and thus aid digestion. It is believed to strengthen the gums and the teeth and cleanses and deodorises the mouth. It is also an appetizer and a stimulant. The offering of betelnuts and flowers, placed on a few leaves of *pan,* in *pujas* or worship is a very common, traditional time honoured practice. So also is the practice of giving *dakshina,* or cash offerings to the *pujari* or the priest, and to the *guru* or the teacher together with betelnuts and betel leaves. Persons held in esteem are offered a few pieces of arecanut with betel leaves as a sign of respect and welcome while entering the house. Again, exchange of betelnut with betel leaves between marriage contracting parties is an important part of betrothel ceremonies. It was also a common practice for long, among the cultivating tenants in Kerala and Karnataka and perhaps in other states as well, to offer the landlord a few arecanuts while paying the rent.

Gode (1961) on the strength of literary sources, mentioned that the history of betelnut chewing among the Aryans in India, at least for the last 2,000 years could be easily established. He also supported the view that *tambula* came into vogue somewhere about the early Gupta period, *i.e.,* about the first or the second century A.D. Kane (quoted by Gode, 1961), in his *History of Dharmasastra* (earlier than A.D. 1524), recorded that *tambula* was probably introduced in India sometime before or about the beginning of the Christian era in the south and it then spread northward.

The chewing habit is prevalent in other countries also, such as Nepal, Sri Lanka, Burma, Thailand, South China, Sumatra, the Philippines, Africa, Arabia,

Pakistan and Bangladesh. According to Watt (1889), the earliest historic reference by an European to the habit of chewing betelnut occurs in the writings of Marco Polo (1298 A.D.). Again, in the excerpts brought to him, Gode (1961) has produced evidence in regard to the social and cultural aspects of arecanut in India and in the adjacent countries as mentioned by noted antiquarians, like Arthur a Perera, and travellers, like Batutta, Ippolito Desideri, Tavernier, Manucci and I. Tsing. Gode (1961) has also referred to the inscriptions at the time of the Nayaks of Tanjore (Tamil Nadu), referring to the procedure in the receipt of betel leaves and betelnuts in marriage ceremonies. According to Murthy (1968) in Assam and West Bengal, the role of the arecanut as a leveller, a mediator and above all, as an article of utmost importance in religious ceremonies and in daily use of chewing, is indeed very great.

2. Medicinal uses

With regard to the medicinal properties of the arecanut, Vagbhata (fourth century A.D.) has described its use against leucoderma, leprosy, cough, fits, worms, anaemia and obesity. Arecanut has also been mentioned for its use as a purgative and in an ointment along with several other ingredients, for the treatment of nasal ulcers. Bhavamista (thirteenth century A.D.) mentioned the use of arecanut as a stimulant and an appetizer. In the *Hithopadesa,* arecanut is described as pungent, bitter, spicy and sweet, and that it expels gas, removes phlegm and bad odour and kills worms. According to Watt (1889), the powdered nuts were held in repute as an antihelminthic for dogs for many centuries, for its efficacy in the expulsion of tapeworms.

IV. Cultivation of arecanut and its economic importance

The evidences adduced in the foregoing sections on the antiquity of arecanut, of the chewing habit and of the multifarious uses to which arecanut is put in our every day life bear out amply that the arecanut has been in cultivation and use in India from time immemorial. Extensive coastal trade and export existed in arecanut during the latter half of nineteenth century has been mentioned by Watt (1889). Gode (1961) stated that South Kanara (in Karnataka) is famous for the betelnut, as it appeared to have been more than 1,200 years ago. He also quoted evidences to show that betelnut plantations were a regular feature of the agricultural economy of Bengal from 1100 to 1300 A.D.

Though the arecanut chewing habit is still prevalent throughout Asia, it is only in India that the crop is cultivated and research on various aspects of this palm is being carried out. Cultivation is practised along the narrow coastal belt,

extending from Kutch, down south to Maharashtra, Karnataka, Kerala and in the east coast of Tamil Nadu, Andhra Pradesh and Orissa, Tripura, Bengal and Assam with the largest concentration in the South West India.

As regards the economic importance of betelnut in India, the total area under the crop during 1980–'81 was 1,84,500 ha, of which 60,900 ha were in Kerala, 54,300 ha in Karnataka 50,800 ha in Assam, 6,500 ha in Meghalaya, 4,300 ha in Tamil Nadu, 3,100 ha in West Bengal; the remainder lies in the states of Andhra Pradesh, Maharashtra, Goa and Tripura. The total production during 1980–'81 was 1,91,400 tonnes, valued at Rs. 2,500 million. Nearly four million persons depend on the arecanut industry in the country; to several lakhs of them, arecanut continues to be the sole means of livelihood.

V. Organisation of arecanut research and development

In spite of the importance which the crop had been enjoying over centuries, very little research work had been done on arecanut other than perhaps the pioneering work of Coleman (1910) on *koleroga* or the fruit rot disease, in the erstwhile Mysore State. Scientific knowledge on agronomic and other requirements for ensuring profitable yields was lacking. Cultivation was on limited scale. The yields were low and the bearing irregular, excepting in some intensively cultivated areas along coastal Kerala and Karnataka. Crop losses, sometimes colossal, due to diseases and pests and unknown causes, were frequent. The industry did not enjoy any protection either, and substantial quantities of arecanut used to be imported from the neighbouring countries, such as Sri Lanka, Burma and Malaya. There was therefore, no incentive, either to adopt intensive cultivation methods or to increase the area under cultivation. It should however be said to the credit of the some arecanut growers, especially in Kerala and Karnataka, that as a result of experience gained with the crop requirements, they were able to obtain high yields and save crop losses to a considerable extent.

However, in the late fourties the governments of the major arecanut cultivating states, Kerala and Karnataka, the growers, the traders and the consumers realised the immense economic potentialities of the crop to the country, the urgent and imperative need to increase production by adopting improved cultivation methods and extending cultivation, and the need to provide protection to the industry by restricting imports. This need was highlighted to the Government of India, who thereupon, constituted an *ad hoc* Arecanut Committee in 1947 followed by the Indian Central Arecanut Committee in 1949 with headquarters at Calicut in

Kerala, to go into the problems of the industry and suggest ways and means to ameliorate its condition and rehabilitate and develop it.

The government of the erstwhile composite Madras State having realised the need for initiating research on arecanut, started a small research unit in 1952 and initially a field experiment was laid out in a private garden known as "Rajas Garden" at Vittal in South Kanara district (now in Karnataka). The objective of this research unit was limited to investigating the etiology of stem breaking in arecanut palm and evolve suitable remedial measures against this malady. The Indian Central Arecanut Committee after its formation opened a research station in April 1956, for the crop, at Vittal called the Central Arecanut Research Station. Subsequently, five Regional Stations were also started during 1958–'59 at Palode and Peechi (both in Kerala), Hirehalli (Karnataka), Mohitnagar (West Bengal), and Kahikuchi (Assam). The Vittal Station lies in the heart of the major arecanut growing areas of the country and the soil and climatic conditions are ideal for the growth of the crop. The station was intended to conduct fundamental and applied research on plant production and protection aspects. With the acquisition of land in 1956, research work started in the right earnest with the planting of two hectares of bulk garden stocked with more than 3,000 seedlings derived from 41 selected families. The earlier work carried out in the "Rajas Garden" by the research unit was subsequently merged with the work of the Central Station.

The important functions of the Regional Stations were to conduct adaptive research to tackle the problems of cultivation and production of arecanut. Consequent to the establishment of the Central Plantation Crops Research Institute (CPCRI) in 1970, the Central Arecanut Research Station became the Regional Station of the Institute and the five Regional Stations of the erstwhile Central Arecanut Research Station became the Research Centres and continued to do research mainly on arecanut. During 1971, a new Research Centre of the CPCRI was opened at Sipighat (Andamans) to take up research on plantation crops in general and arecanut in particular to meet the needs of the Andaman and Nicobar Islands. A Seed Farm of the CPCRI established during 1972 at Kidu (Karnataka), is concerned with the production and distribution of elite seedlings in *Mangala* and other selected high yielding varieties of arecanut along with coconut, cashew and cocoa. The adaptive Research Centres were increased in number under the All India Co-ordinated Project on Coconut and Arecanut Improvement started during 1972. The new centres under the All India Co-ordinated Project are located at Coimbatore (Tamil Nadu), Dapoli (Maharashtra), Arsikere (Karnataka), and Sakhigopal (Orissa).

The developmental work on arecanut which was originally carried out by the Indian Central Arecanut Committee is being looked after at present by the Directorate of Cocoa, Arecanut and Spices Development, the headquarters of which is located at Calicut. Fig. 1.1 gives the centres of arecanut research and development in the country at present.

VI. A success story

Adopting a highly inter-disciplinary approach in the formulation and execution of need-based research programmes, the main centre at Vittal and the five Research Centres during the last two decades developed suitable technology for selecting seeds and seedlings, standardised agro-techniques for raising nursery and establishing arecanut plantations, worked out control measures for pests and diseases and evolved better varieties. The first improved variety *Mangala* was released for cultivation about a decade back. Working out a pattern of inter and mixed cropping in arecanut involving both annuals and perennials in general and arecanut and cocoa in particular, constituted an important mile stone in the progress of research. Concurrently, the Indian Central Arecanut Committee organised large scale production and distribution of quality arecanut seedlings and promoted other production activities through various schemes aimed at adoption of better management and crop protection practices. These research and development efforts had considerable impact on production and productivity of arecanut in the country.

Production of arecanut which was 76,000 tonnes during 1956–'57 got doubled in about 14 years. During the same period the per hectare yield increased from 788 kg to 918 kg. The increase in production has been due to both increase in area and increase in productivity. While the development activities such as establishing nurseries to produce and supply quality seedlings gave boost for expansion of area under arecanut, better agro-techniques, plant protection measures and superior varieties resulting from research, had their influence in increasing the productivity. Thus the country became self-sufficient in its requirement of arecanut in the early seventies.

Achievement of self-sufficiency and the continued increase in production had its immediate effect on the price of arecanut. The price in the internal market has been almost steadily rising ever since the early fifties. With the production touching a figure of 1,41,000 tonnes during 1970–'71, the market showed a downward trend and the price of arecanut crashed from Rs. 795/quintal in 1970–'71 to Rs. 522/quintal (Mangalore market) in 1972–'73.

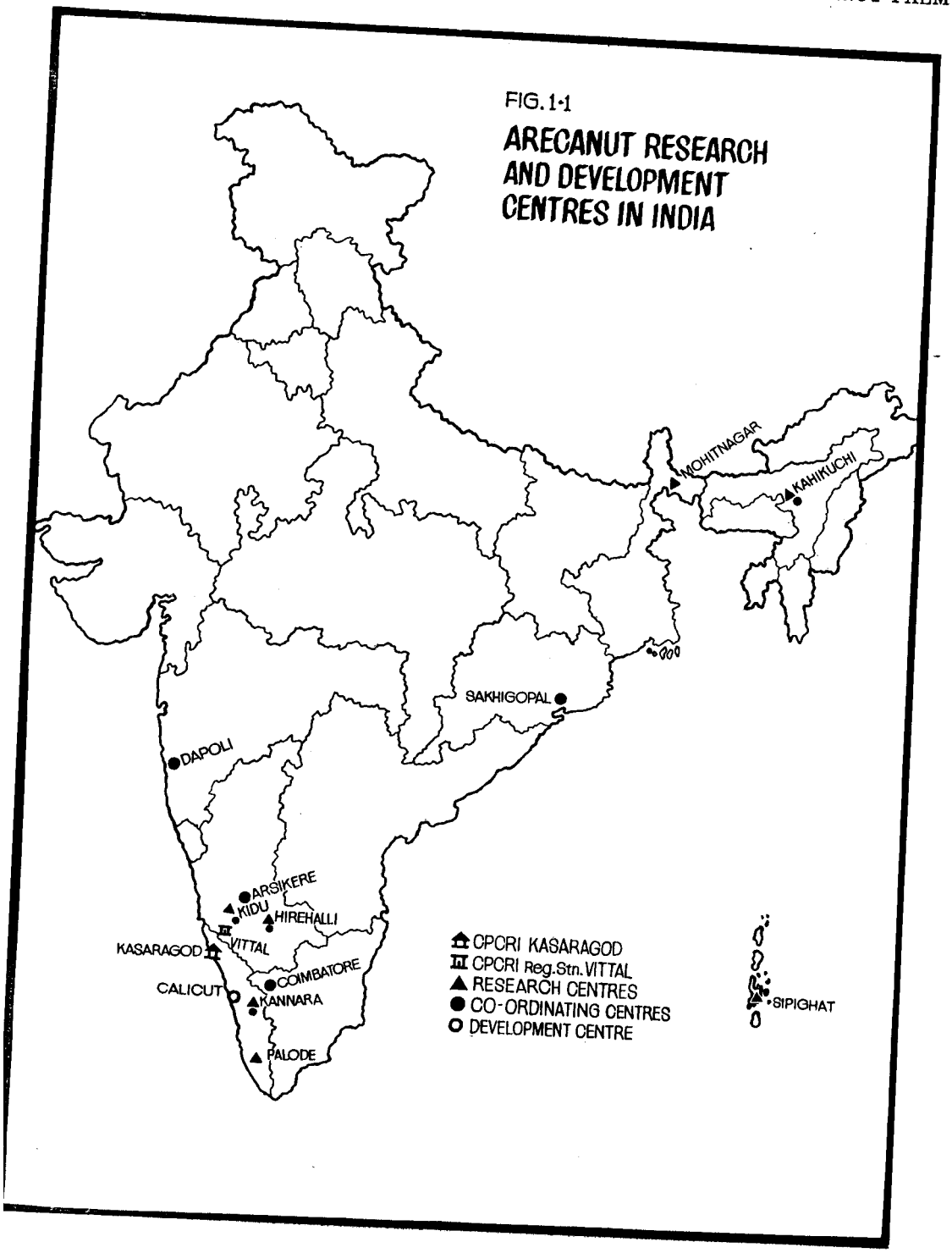
FIG. 1-1
ARECANUT RESEARCH AND DEVELOPMENT CENTRES IN INDIA
MOHITNAGAR
KAHIKUCHI
SAKHIGOPAL
DAPOLI
ARSIKERE
KIDU
HIREHALLI
VITTAL
KASARAGOD
COIMBATORE
CALICUT
KANNARA
PALODE
SIPIGHAT
CPCRI KASARAGOD
CPCRI Reg.Stn.VITTAL
RESEARCH CENTRES
CO-ORDINATING CENTRES
DEVELOPMENT CENTRE

After detailed discussions in different platforms and panels, it was decided to promote a co-operative society of arecanut growers of Karnataka and Kerala states to handle the procurement and marketing of arecanut. It was hoped that by procuring arecanut directly from the growers and supplying the same to the consumer at the nearest point possible, the margins of the middlemen, the delay in movement, handling and many other expenses could be avoided and it would be possible to offer a better price to the producer. With active supports from the Governments of Karnataka and Kerala, The Central Arecanut Marketing and Processing Co-operative Limited, Mangalore popularly called as CAMPCO thus came into existence in the year 1973. The CAMPCO entered the market in November 1973 and succeeded in lifting up the market price in a remarkably short period. Within three months, the prices were restored to the pre-fall level. Since then the CAMPCO has succeeded in offering the arecanut growers a steady price proportionate to the production costs.

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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.*

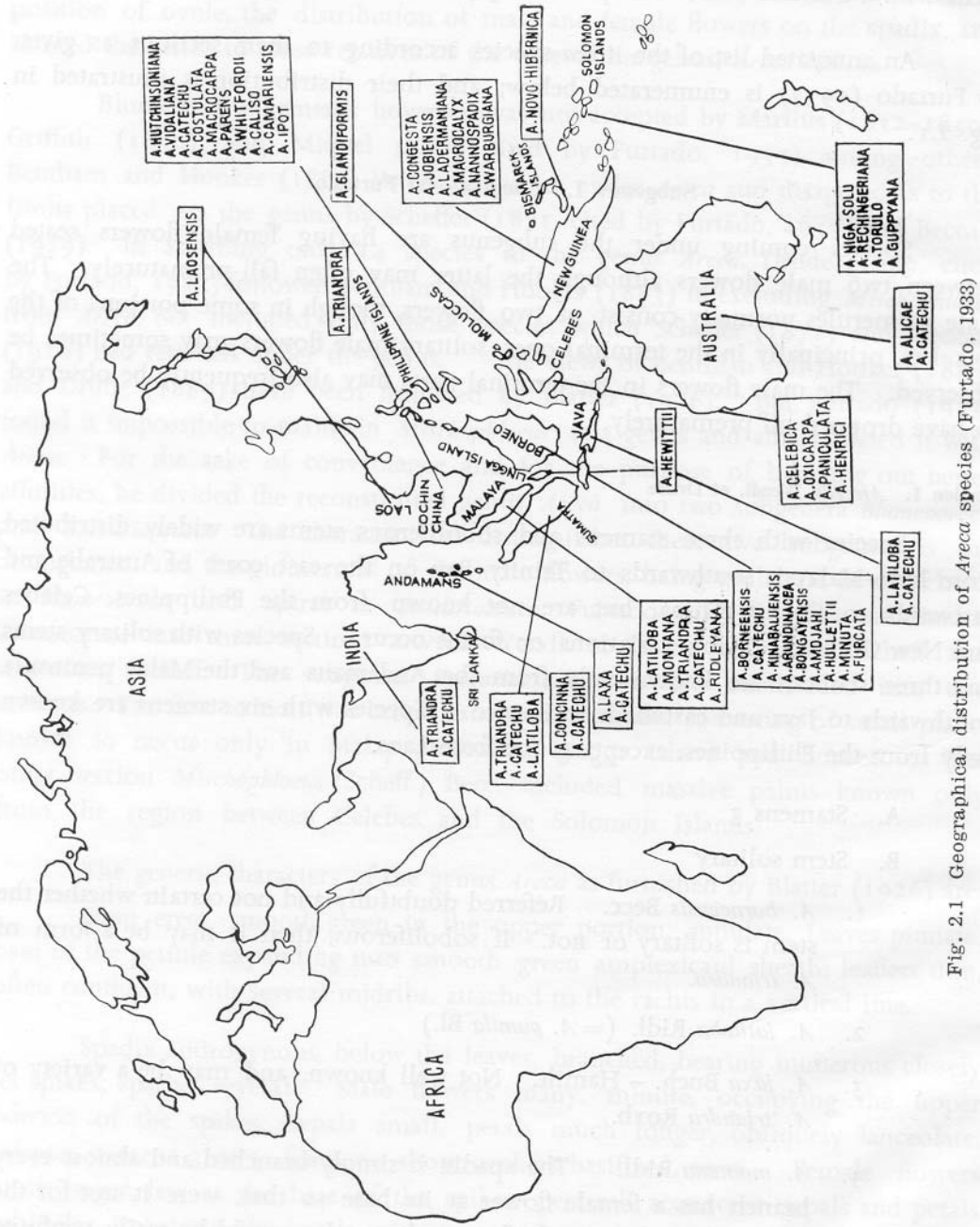


Fig. 2.1 Geographical distribution of *Areca* species (Furtado, 1933)

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

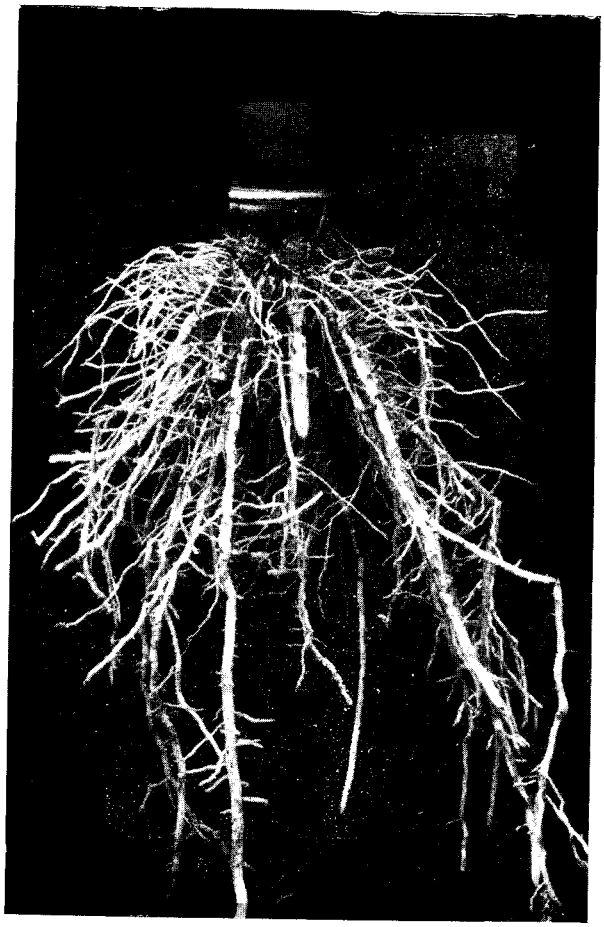


Fig. 2.2 Root system

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)

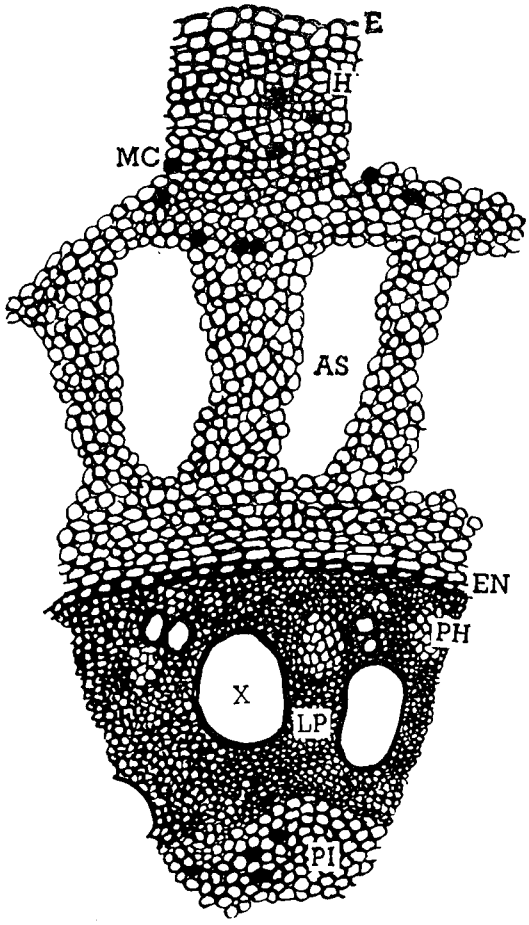


Fig. 2.3 Transverse section of root. *E-Epidermis; H-Hypodermis; MC-Mucilage cells; AS-Air space; EN-Endodermis; X-Xylem; PH-Phloem; LP-Lignified parenchyma; PI-Pith.*

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).

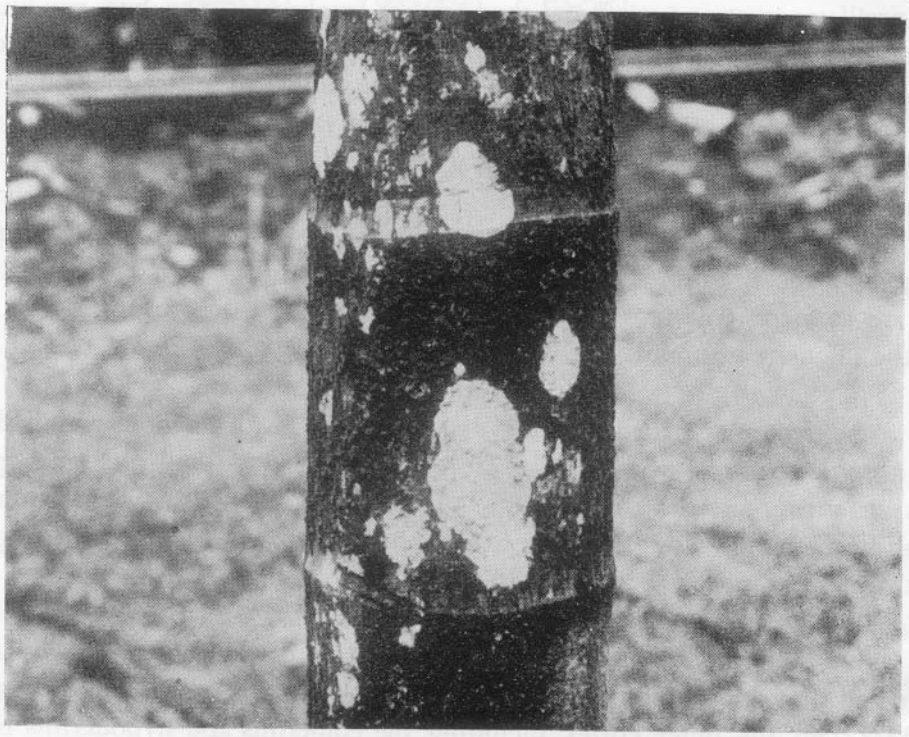


Fig. 24 Arecanut stem showing nodes and lichen growth

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

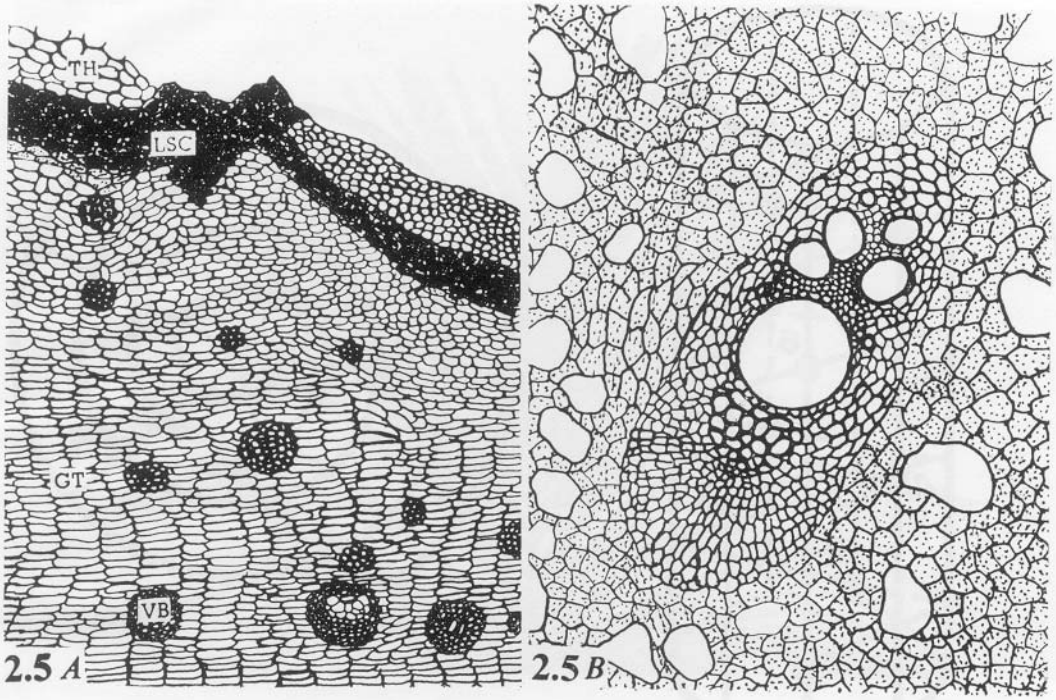
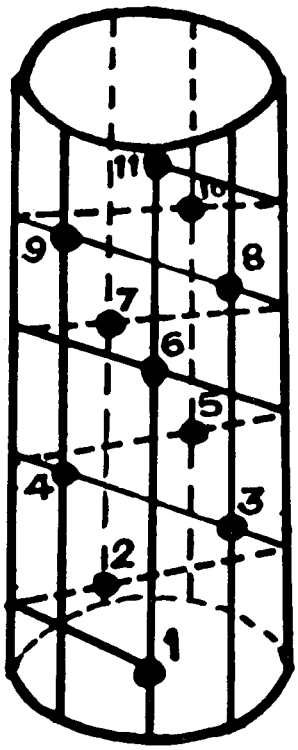


Fig. 2.5A Transverse section of stem. *TH–Thick walled hypodermis; LSC–Ligno-suberised cork; VB–Vascular bundle; GT–Ground tissue.*
Fig. 2.5B Transverse section of stem showing vascular bundle.

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).

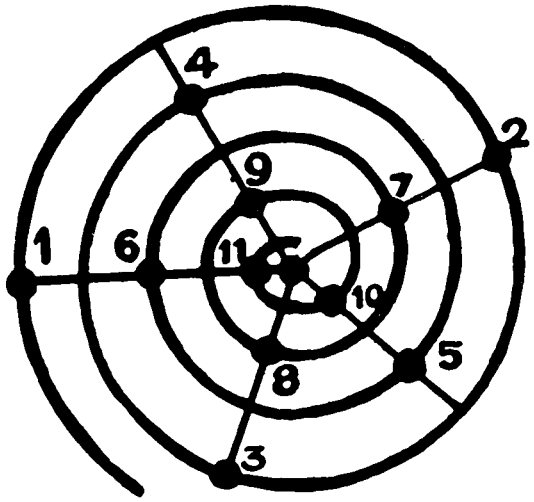
The bud produces leaves in succession and the young leaf makes its appearance in the centre of the crown with all the leaflets held together and is termed as the spindle. As the leaf gets older, it bends and during this process the leaflets get opened. The longevity of the leaf after its emergence is 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,

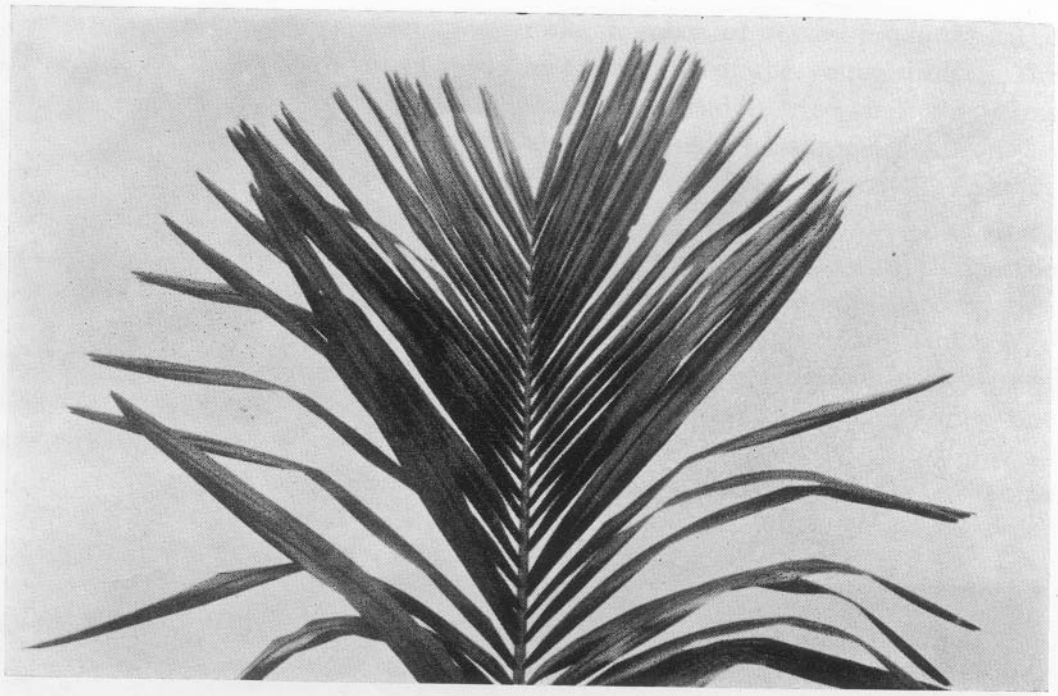


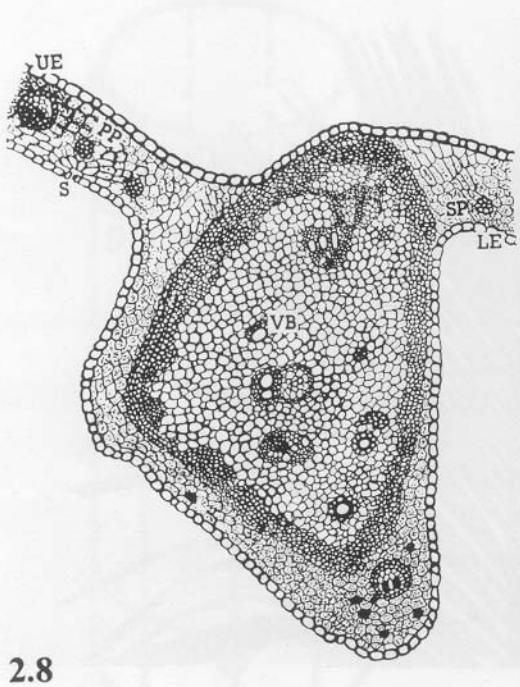
Fig. 2.7 Arecanut leaf showing bifid tip

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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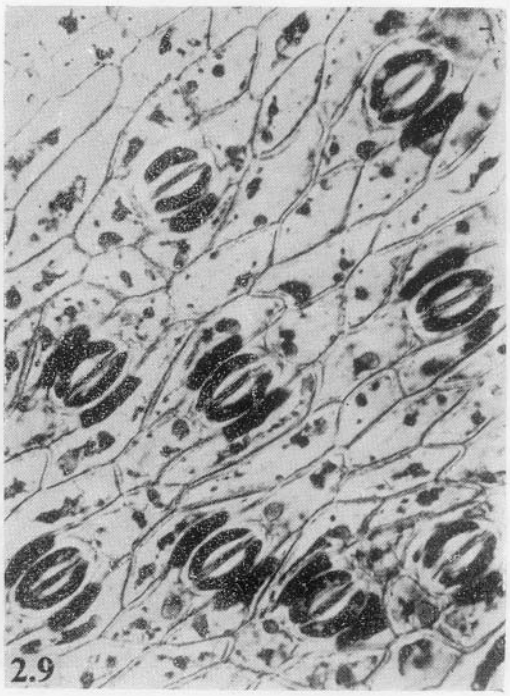


2.9

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

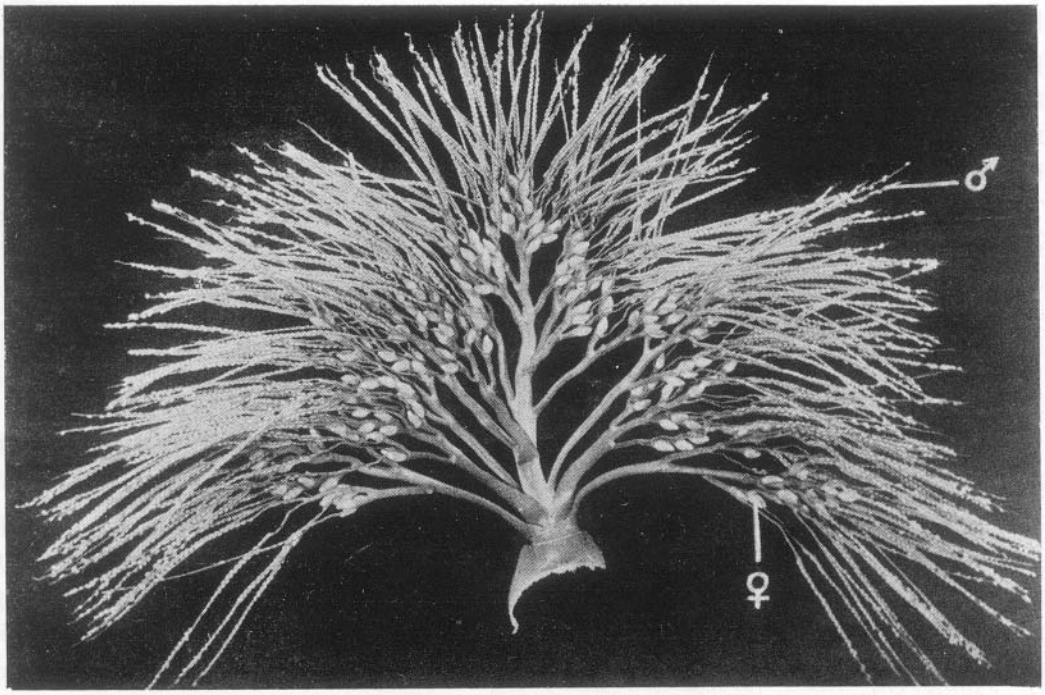


Fig. 2.10 Inflorescence showing male and female flowers

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

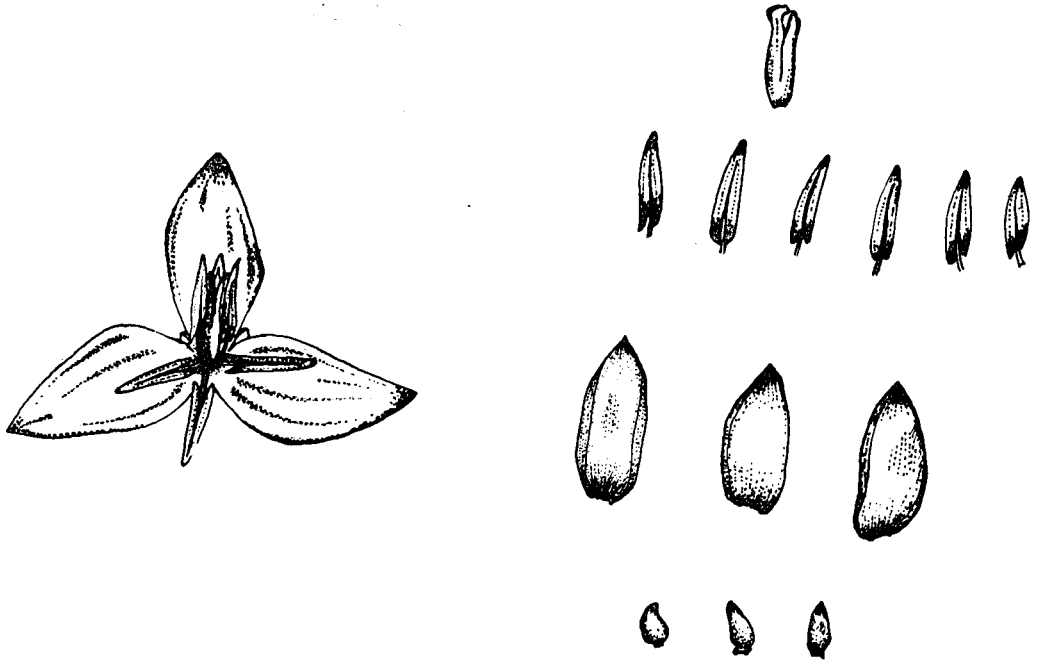


Fig. 2.11A Structure of male flower

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).

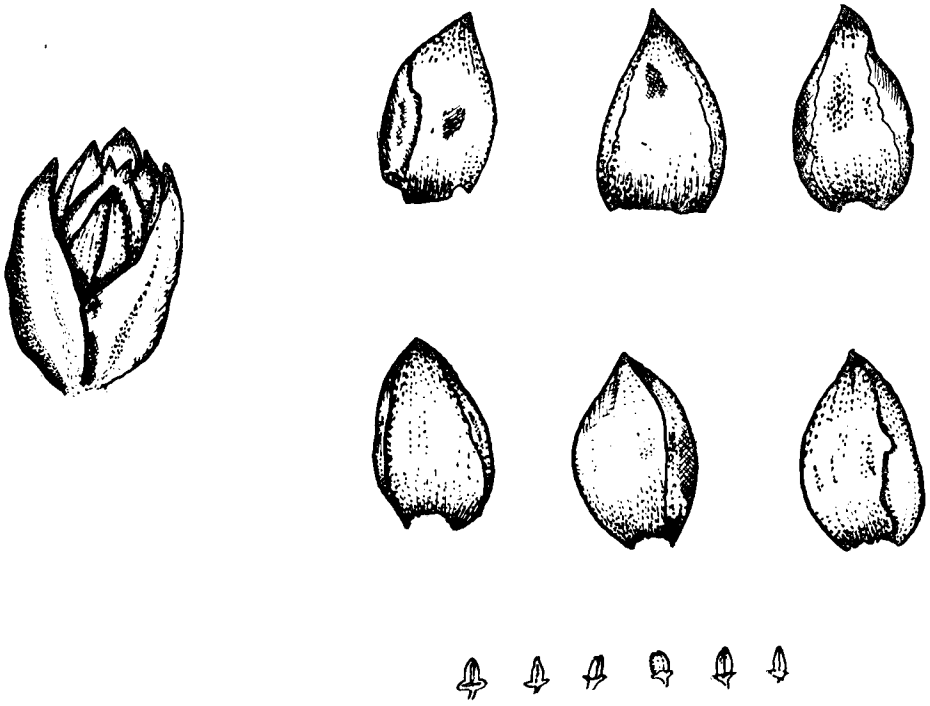


Fig. 2.11B Structure of female flower

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).

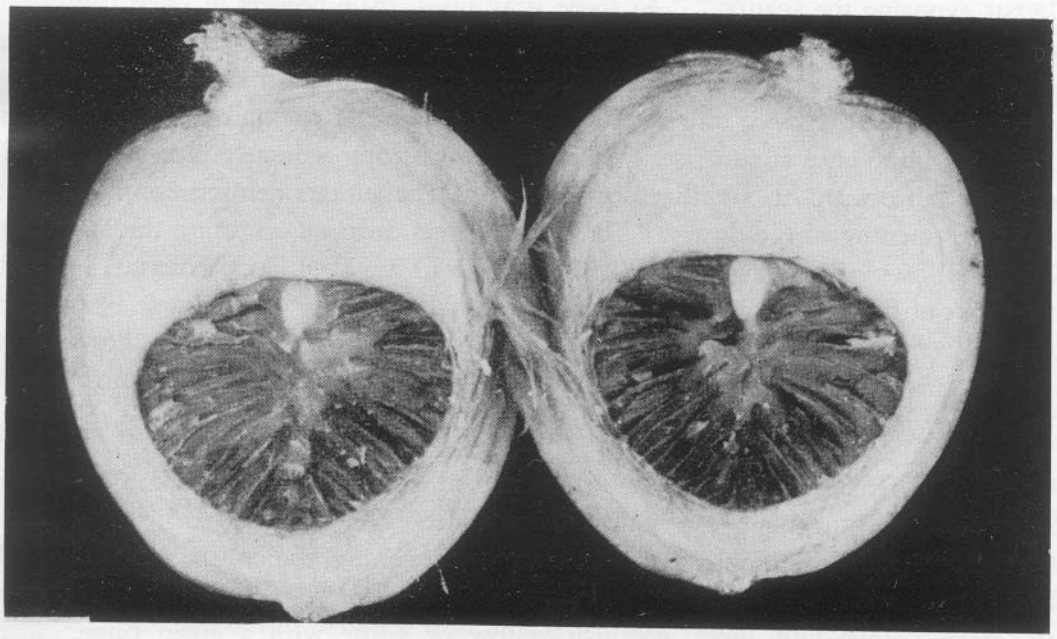


Fig. 2.12 Split nut showing embryo

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).

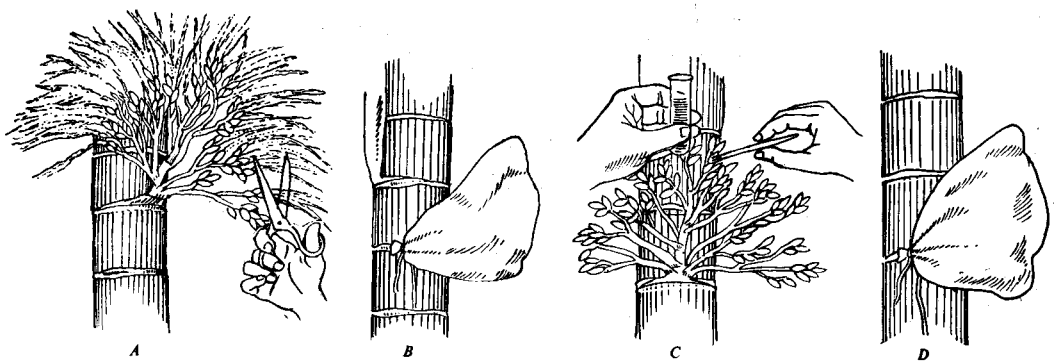


Fig. 2.13A–D Hybridisation technique

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.

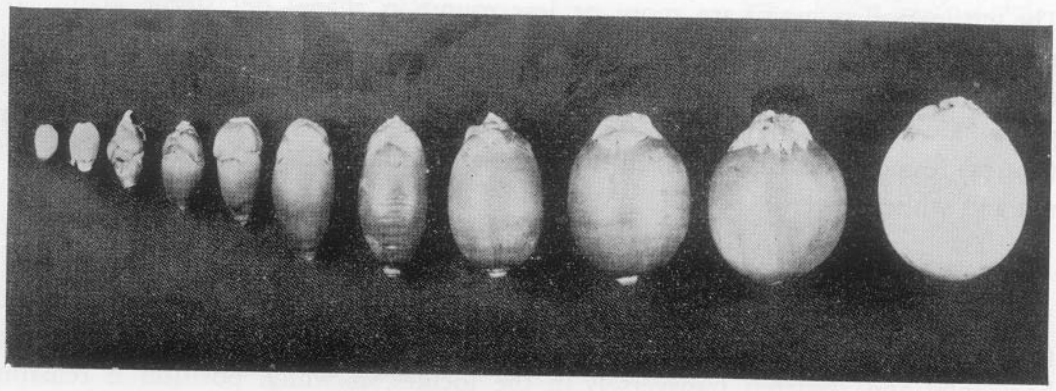


Fig. 2.14 Stages of nut development

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

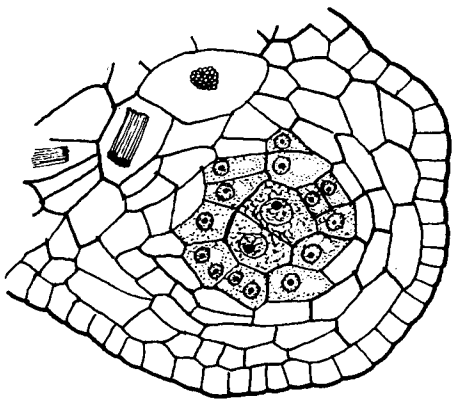
In *A. catechu* the primary sporogenous cells function directly as microspore mother cells (Figs. 2.15 and 2.16). Microspore tetrads are usually tetrahedral (Fig. 2.17) though decussate and bilateral tetrads are occasionally met with. Mature pollen grains are 2–celled, ellipsoidal or nearly spherical 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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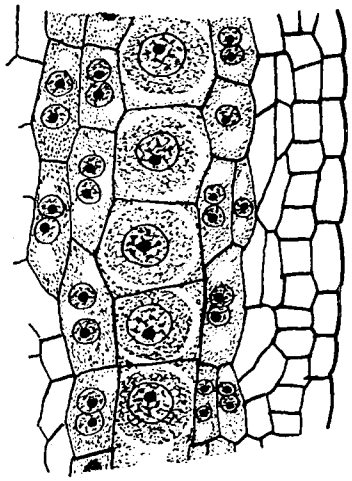

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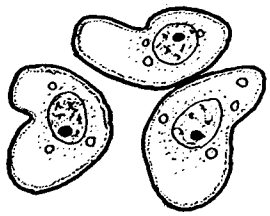

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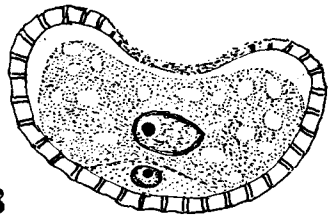

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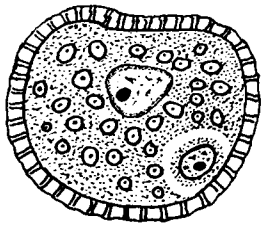

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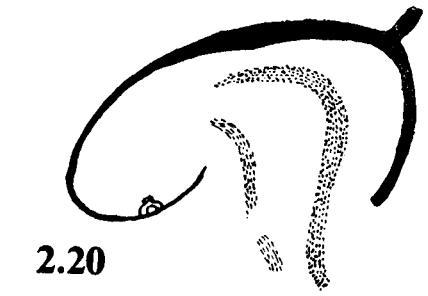
Fig. 2.15 Transverse section of anther locules. Fig. 2.16 Longitudinal section of anther locules. Figs. 2.17—2.19 Developing pollen grains.



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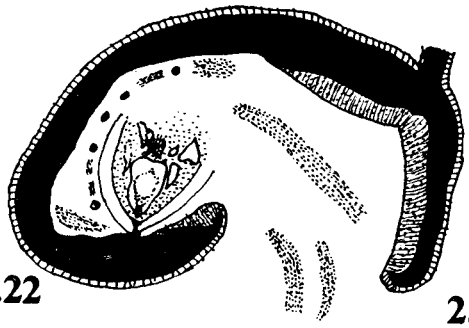

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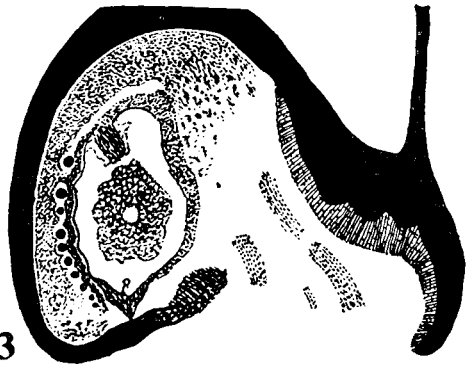

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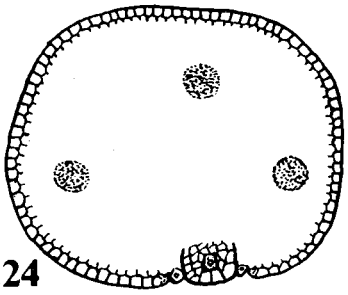

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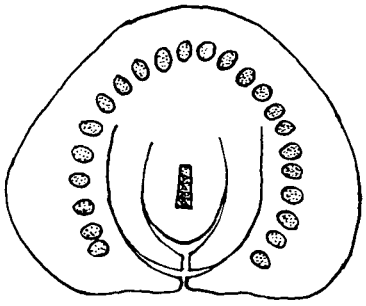

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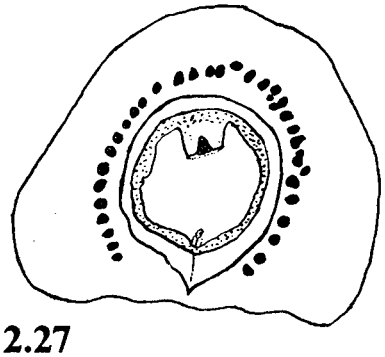

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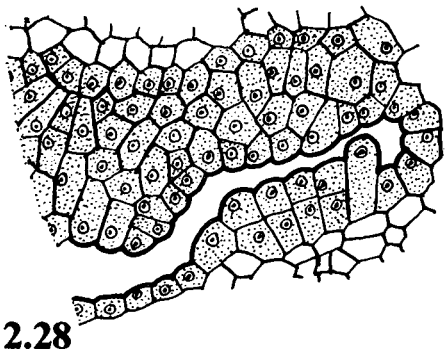


2.28

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

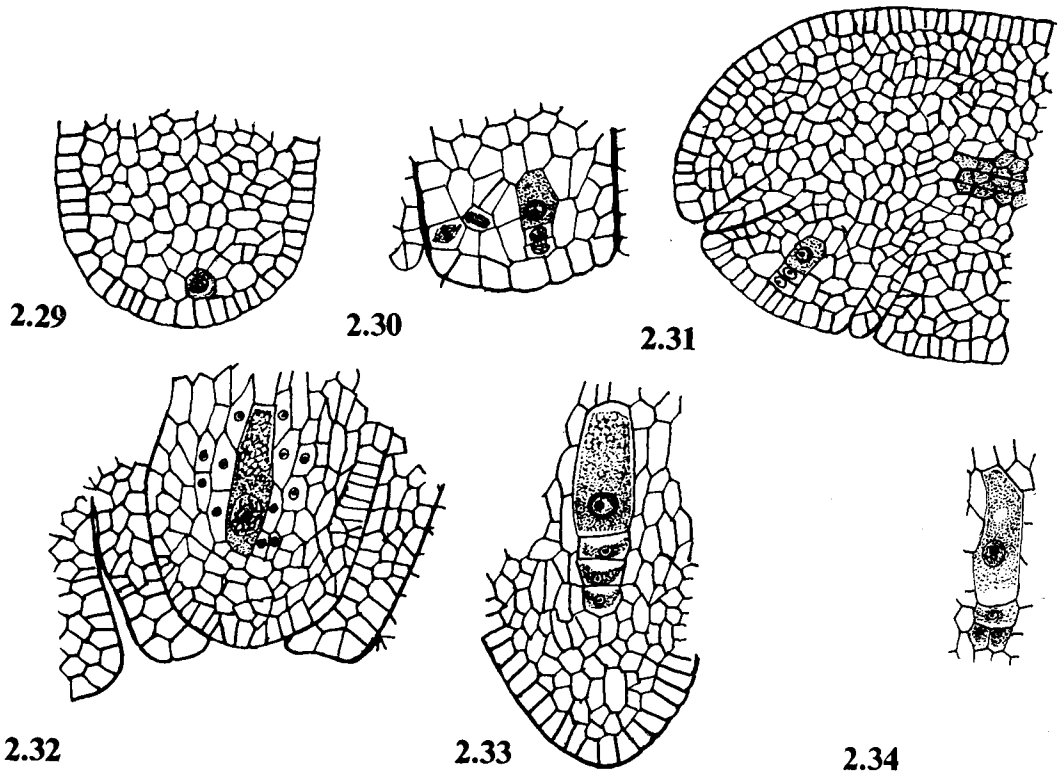
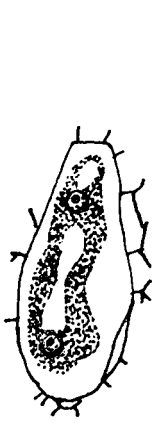


Fig. 2.29 Longitudinal section of ovule primordium with archesporium. Figs. 2.30—2.31 Formation of parietal layers. Fig. 2.32 Nucellus with full grown megaspore mother cell. Fig. 2.33 Linear shaped megaspore tetrad. Fig. 2.34 T shaped megaspore tetrad.

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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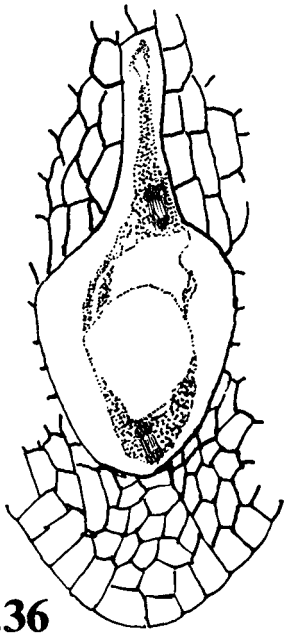

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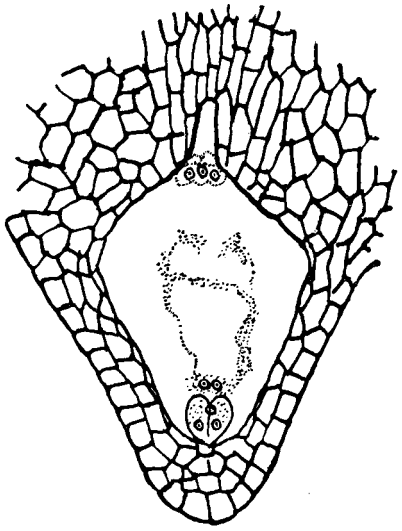

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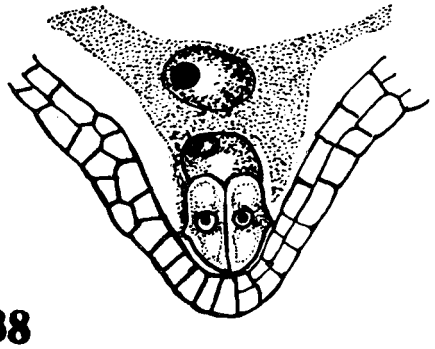

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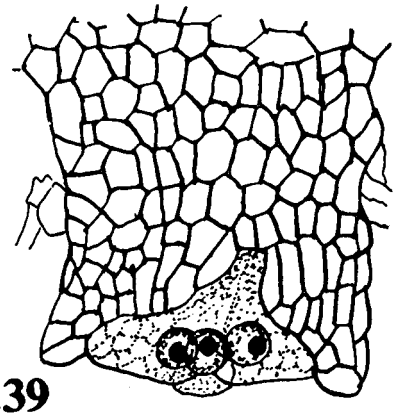


2.39

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)

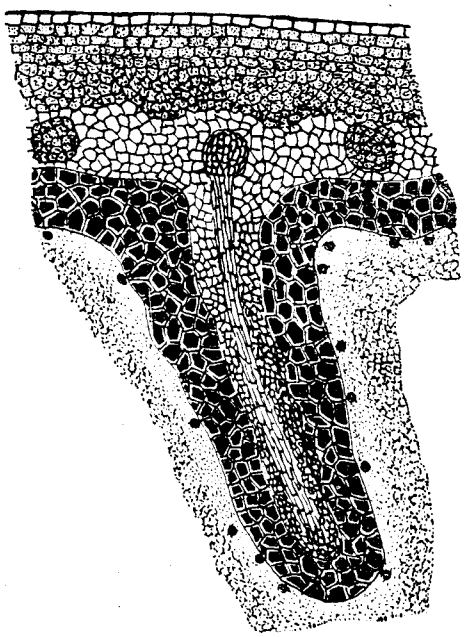


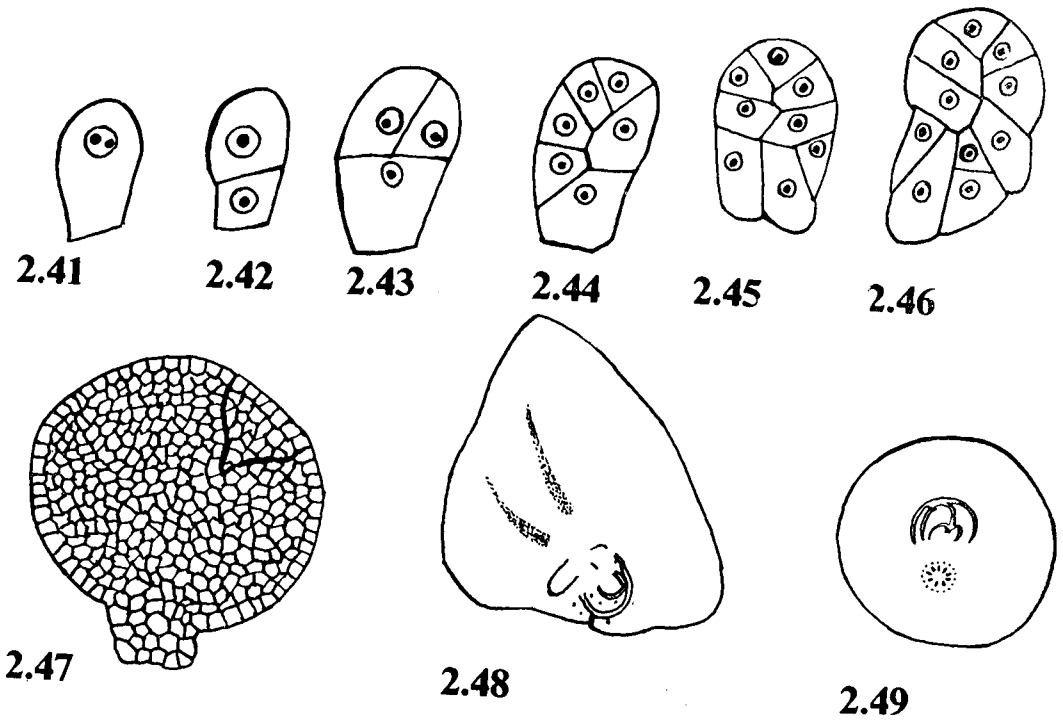
Fig. 2.40 Longitudinal section through rumination

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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3

CYTOGENETICS AND BREEDING

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The breeding system of arecanut palm (*Areca catechu* L.), its perennial habit and the long juvenile phase constitute the chief barriers in undertaking cytogenetic and breeding investigations in this crop. The role of cytogenetic investigation in determining the phylogenetic relationship in the family Palmae was first suggested by Sharma and Sarkar (1956). Since then, detailed cytological information, such as chromosome number, meiotic behaviour, chromosome size and morphology, have been reported atleast in the *Areca* spp. through a series of papers (Bavappa and Raman, 1965; Bavappa, Nair and Ratnambal, 1975; Bavappa and Nair, 1978). In recent years newer and sophisticated biometrical techniques have been employed in crop improvement and phylogenetic studies. These methods have been extensively used in improvement of arecanut crop also (Bavappa and Ramachander, 1967a, 1967b, 1968a, 1968b). The usefulness of multivariate analysis to classify *Areca* species and cultivars based on genetic divergence has also been indicated by Bavappa (1974) in an extensive study.

I. Cytogenetics

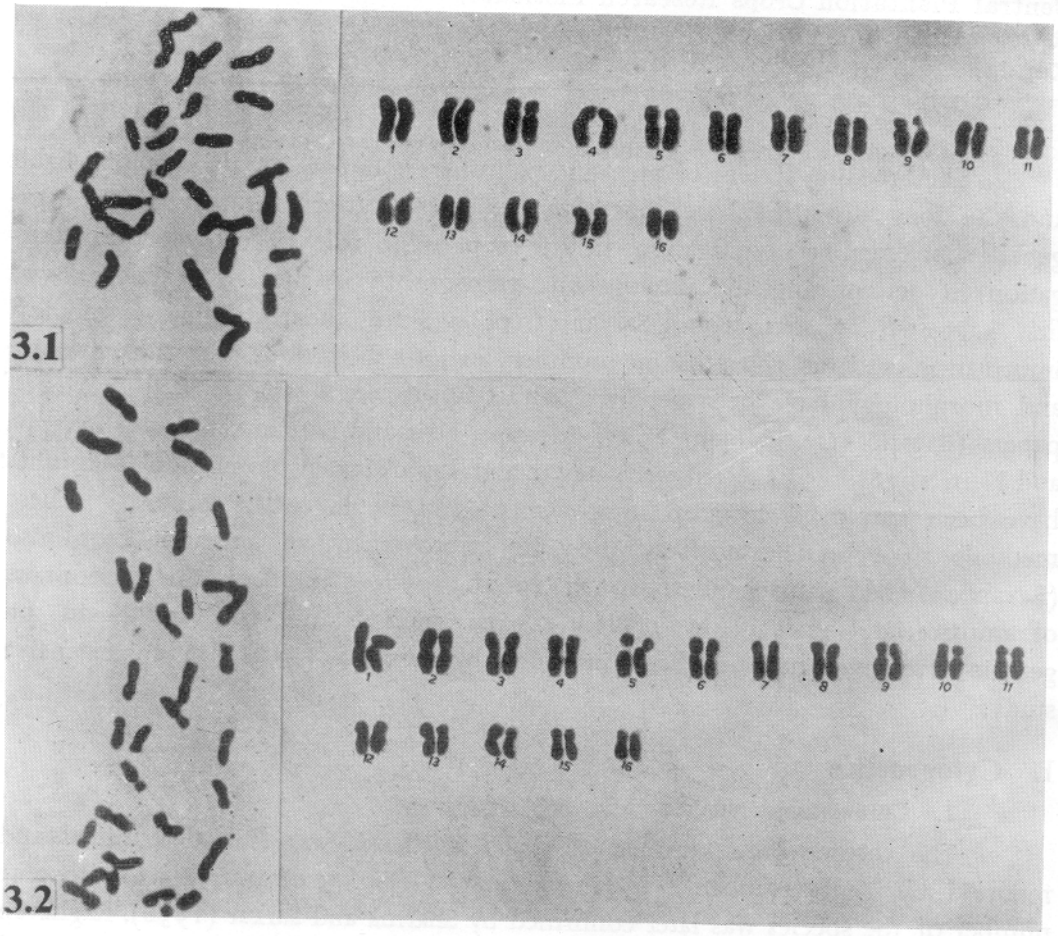
1. Chromosome number

The chromosome number of *Areca catechu* L. was first determined and reported by Venkatasubban (1945) as 2n=32 (Fig. 3.1). The chromosome number of the species was later confirmed by Sharma and Sarkar (1956), Raghavan and Baruah (1958), Abraham, Mathew and Ninan (1961) and Bavappa and Raman (1965).

A chromosome number of 2n=32 reported by Darlington and Janaki Ammal (1945) for *A. triandra* Roxb. was later confirmed by Sharma and Sarkar (1956) and Bavappa and Raman (1965) (Fig. 3.2). Nair and Ratnambal (1978) determined the meiotic chromosome number of *A. macrocalyx* Becc. as n=16 (Fig. 3.3).

2. Meiosis

Meiotic abnormalities such as non-disjunction, lagging chromosomes, univalents and pentads were reported in *A. catechu* by Sharma and Sarkar (1956).



Figs. 3.1—3.2 Somatic chromosomes in *Areca* spp.
Fig. 3.1 A. catechu *2n=32; Fig. 3.2* A. triandra *2n=32.*

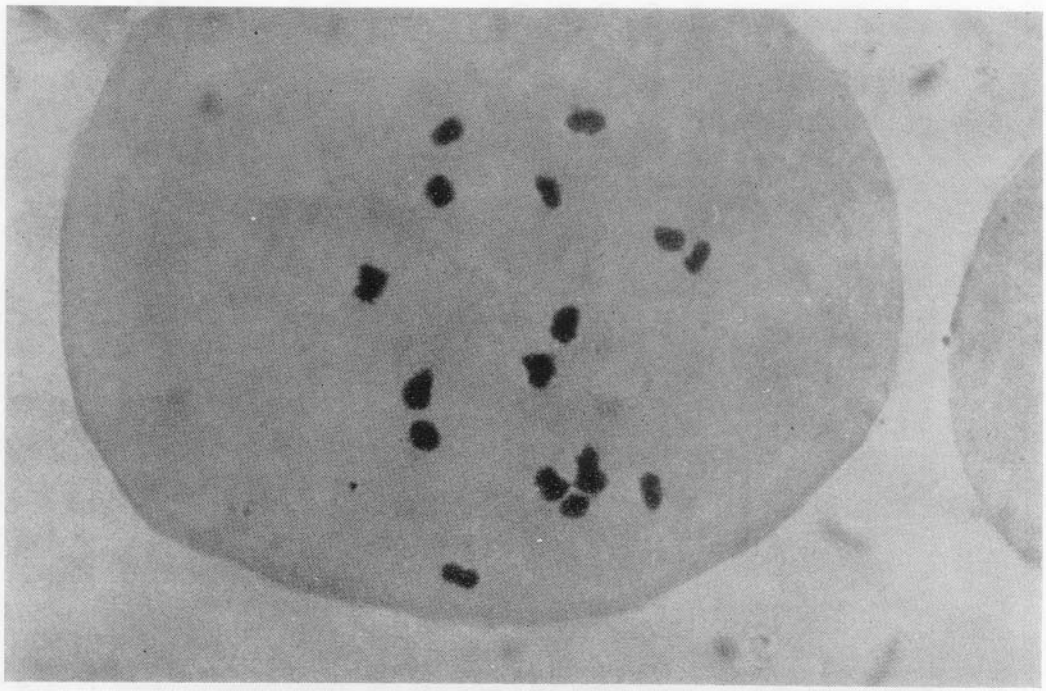
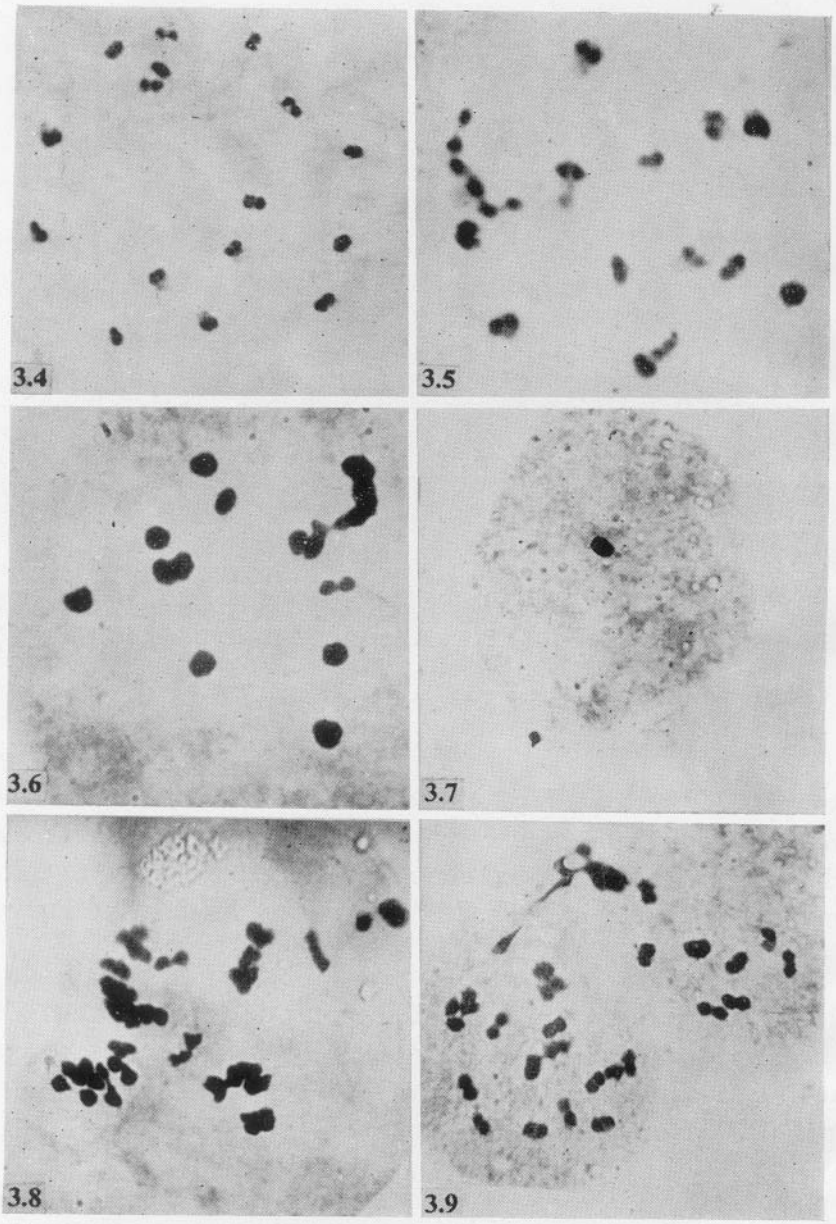


Fig. 3.3 Meiotic chromosomes in *A. macrocalyx* n=16 (1 IV+14 II)

Bavappa and Raman (1965) observed in the meiosis of four ecotypes of *A. catechu,* abnormalities like univalents at diakinesis and metaphase I, non-synchronisation of orientation, clumping, delayed disjunction, chromosome bridges and laggards at anaphase I and II, chromosome mosaics and supernumerary spores.

Sharma and Sarkar (1956) found the meiotic division quite normal in *A. triandra* except for the presence of 14 and 18 chromosomes occasionally at metaphase II. Bavappa and Raman (1965) also reported regular meiotic division in the types of *A. triandra* studied by them.

Intra-cultivar variation in meiotic behaviour of *A. catechu* was reported by Bavappa (1974) and Bavappa and Nair (1978). While normal bivalent formation was observed in some palms (Fig.3.4), others had maximum association of hexavalents (Fig. 3.5) octovalent and even decavalent (Fig. 3.6; Table 3.1). Abnormalities like bridges and laggards, disorientation of chromosomes at anaphase I and anaphase II were also reported in this species (Table 3.2).



Figs. 3.4—3.9 Microsporogenesis in *A. catechu* and *A. triandra*. *Fig. 3.4* A. catechu *Local (717), early M I, 16 II; Fig. 3.5* A. catechu *China (111), diakinesis, I VI+13 II; Fig. 3.6* A. catechu *Local (471), diakinesis, I X+ I IV+ 9 II; Fig. 3.7* A. triandra *Ceylon–3 (55) 1 II+1 I; Fig. 3.8* A. triandra *Ceylon–3 (55), 27 II+1 I; Fig. 3.9* A. triandra *Ceylon–3 (87), Cytomixis.*

Table 3.1. *Chromosome association at diakinesis and metaphase I in* A. catechu, A. triandra *and their hybrids*

Species/hybrids	Diakinesis						Metaphase I						
	No. of PMCs observed	Above quadrivalent (Mean)	IV Range (Mean)	III Range (Mean)	II Range (Mean)	I Range (Mean)	No. of PMCs observed	Above hexavalent (Mean)	VI Range (Mean)	IV Range (Mean)	III Range (Mean)	II Range (Mean)	I Range (Mean)
A. catechu													
Local (471)	82		0–2 (0.67)		12–16 (14.66)		53	0.02 X+ 0.08 VIII	0–2 (0.17)	0–5 (0.60)	0–2 (0.16)	4–16 (13.59)	0–2 (0.08)
Local (717)	100				11–16 (15.64)	0–10 (0.72)	87					15–16 (15.96)	0–2 (0.08)
China (111)	82	0.01 VI	0–2 (0.15)		12–16 (15.55)	0–4 (0.24)	63		0–1 (0 02)	0–2 (0.16)		9–16 (15.62)	
China (175)	80		0–2 (0.24)	0–1 (0.01)	12–16 (15.45)	0–2 (0.11)	43		0–1 (0.02)	0–2 (0.21)		13–15 (15.52)	
A. triandra													
Ceylon-3 (55)	55				8–16 (12.68)	0–14 (6.64)	84				0–1 (0.01)	14–16 (15.73)	0–2 (0.51)
Ceylon-3 (70)	80				6–16 (13.74)	0–20 (4.52)	76					13–16 (15.71)	0–6 (0.58)
Ceylon-3 (87)	96		0–1 (0.03)		7–16 (12.85)	0–18 (6.18)	66					8–16 (14.65)	0–16 (2.70)
Mauritius (109)	49			0–1 (0.06)	5–16 (12.12)	0–22 (7.58)	71				0–2 (0.10)	4–16 (13.46)	0–24 (4.78)
Indonesia-2 (154)	38				4–15 (11.05)	1–24 (9.90)	36			0–1 (0.03)	0–1 (0.03)	8–16 (14.59)	0–16 (2.41)
A. catechu × *A. triandra*													
Palm No. 248	107	0.31VIII+ 0.01VI+ 0.01IV	0–2 (0.10)	0–3 (0.40)	2–14 (8.92)	0–28 (12.37)	61		0–1 (0.02)	0–1 (0.02)	0–2 (0.12)	5–16 (14.07)	0–10 (3.30)
Palm No. 287	90			0–1 (0.08)	0–16 (11.24)	0–32 (9.28)	114				0–1 (0.06)	10–16 (14.83)	0–9 (2.16)
Palm No. 288	82		0–1 (0.13)	0–1 (0.05)	8–16 (14.34)	0–14 (2.65)	81			0–1 (0.09)	0–1 (0.06)	11–16 (15.33)	0–6 (0.90)
Palm No. 307	65				1–16 (10.34)	0–30 (11.32)	97				0–1 (0.01)	13–16 (15.73)	0–6 (0.51)
Spontaneous hybrid	57		0–1 (0.04)	0–1 (0.09)	4–16 (9.90)	5–24 (11.77)	39				0–1 (0.05)	11–16 (14.33)	0–10 (3.19)

Table 3.2. *Abnormalities at later stages of meiosis, pollen fertility and nut set in* A. catechu, A. triandra *and their hybrids*

Species/hybrids	Anaphase I		Anaphase II		Tetrads							
	No. of cells observed	Cells with bridges, laggards and disorientation %	No. of cells observed	Cells with bridges, laggards and disorientation %	No. of cells observed	Micronuclei (%)	Monads (%)	Diads (%)	Triads (%)	Super numerary spores (%)	Pollen fertility (%)	Nut set (%)
A. catechu												
Local (471)	121	9.1	84	10.7	171	0.0	0.0	0.0	12.3	0.0	95.4	26.4
Local (717)	123	11.4	67	1.5	144	0.8	0.0	1.4	2.0	0.0	82.7	36.9
China (111)	163	0.6	70	0.0	67	0.0	0.0	0.0	3.0	0.0	98.2	42.2
China (175)	95	6.3	63	4.8	106	0.0	0.0	2.8	10.4	0.0	95.7	12.0
A. triandra												
Ceylon-3 (55)	148	26.4	81	11.1	178	1.7	0.5	1.7	2.8	0.0	75.5	36.4
Ceylon-3 (70)	110	8.2	67	1.5	140	0.0	0.0	0.7	12.9	0.7	65.4	42.1
Ceylon-3 (87)	106	17.9	77	15.6	147	4.1	0.0	0.7	13.6	2.7	63.3	28.1
Mauritius (109)	44	29.5	41	26.8	175	14.9	1.7	4.6	6.8	0.0	33.1	33.8
Indonesia-2 (154)	80	18.8	57	24.6	164	1.8	1.2	0.0	4.3	0.0	45.2	41.3
A. catechu × *A. triandra*												
Palm No. 248	89	69.7	44	52.3	137	22.6	0.0	2.2	16.1	2.9	3.7	0.5
Palm No. 287	109	14.7	117	16.2	148	4.7	0.0	0.7	8.8	0.0	0.5	0.3
Palm No. 288	87	29.9	93	26.9	185	4.6	0.0	3.2	11.8	4.8	8.3	0.0
Palm No. 307	46	71.7	80	37.5	133	10.9	0.7	0.4	2.3	0.4	6.1	0.0
Spontaneous hybrid	71	46.5	66	31.8	143	12.6	6.3	9.8	15.4	0.0	0.1	0.0

Intra-palm variation in chromosome numbers in the pollen mother cells of *A. catechu, A. triandra* and their hybrids was reported by Bavappa and Nair (1978) (Fig. 3.7 and 3.8; Table 3.3) and cytomixis to an extent of 39% seemed to have contributed to this abnormality (Fig. 3.9). In spite of high degree of multivalents in *A. catechu,* pollen fertility was very high. The possibility of the frequency of multivalent formation and disjunction being under genotypic control and being subjected to selection was suggested by Bavappa and Nair (1978).

Table 3.3. *Intra-palm variation in chromosome number at meiosis in* A. catechu, A. triandra *and their interspecific hybrids*

Species/hybrids	Meiotic stage	Number of PMCs observed	Number of PMCs with chromosome mosaic	Percentage	Range of chromosome association
A. catechu					
Local (471)	Diak.	82	–	–	
	MI	53	–	–	
Local (717)	Diak.	102	2	2.0	15II
	MI	87	–	–	–
China (111)	Diak.	88	6	6.8	6II to 1IV+13II
	MI	66	3	4.5	6II to 15II
China (175)	Diak.	80	–	–	–
	MI	43	–	–	–
A. triandra					
Ceylon-3 (55)	Diak.	72	17	23.6	5II+1I to 17II
	MI	98	14	14.3	1II+1I to 27II+1I
Ceylon-3 (70)	Diak.	87	7	8.0	8II+3I to 15II
	MI	81	5	6.2	12II to 19II
Ceylon-3 (87)	Diak.	103	7	6.8	5II+5I to 15II
	MI	73	7	9.6	2II to 18II+1Fr
Mauritius (109)	Diak.	56	7	12.5	4II+3I to 1IV+1III+7II+13I
	MI	79	8	10.1	7II to 1III+9II+13I
Indonesia-2 (154)	Diak.	38	–	–	–
	MI	37	1	2.7	15II+1Fr
A. catechu × *A. triandra*					
Palm No. 248	Diak.	119	12	1.0	1II+3I to 1VI+8II+4I
	MI	64	3	4.6	12II+6I to 1III+10II+3I
Palm No. 287	Diak.	97	7	7.2	4II+3I to 1III+2II+8I
	MI	117	3	2.6	8II to 1III+13II+1I
Palm No. 288	Diak.	87	5	5.7	2II+2I to 1III+14II+3I
	MI	85	4	4.7	14II to 1III+13II+2I
Palm No. 307	Diak.	72	7	9.7	6II to 27II+2I
	MI	105	8	7.6	11II to 1III+13II+2I
Spontaneous hybrid	Diak.	60	3	5.0	13II+15I to 1III+9II+9I
	MI	44	4	9.1	15II+1I to 9II to 12I

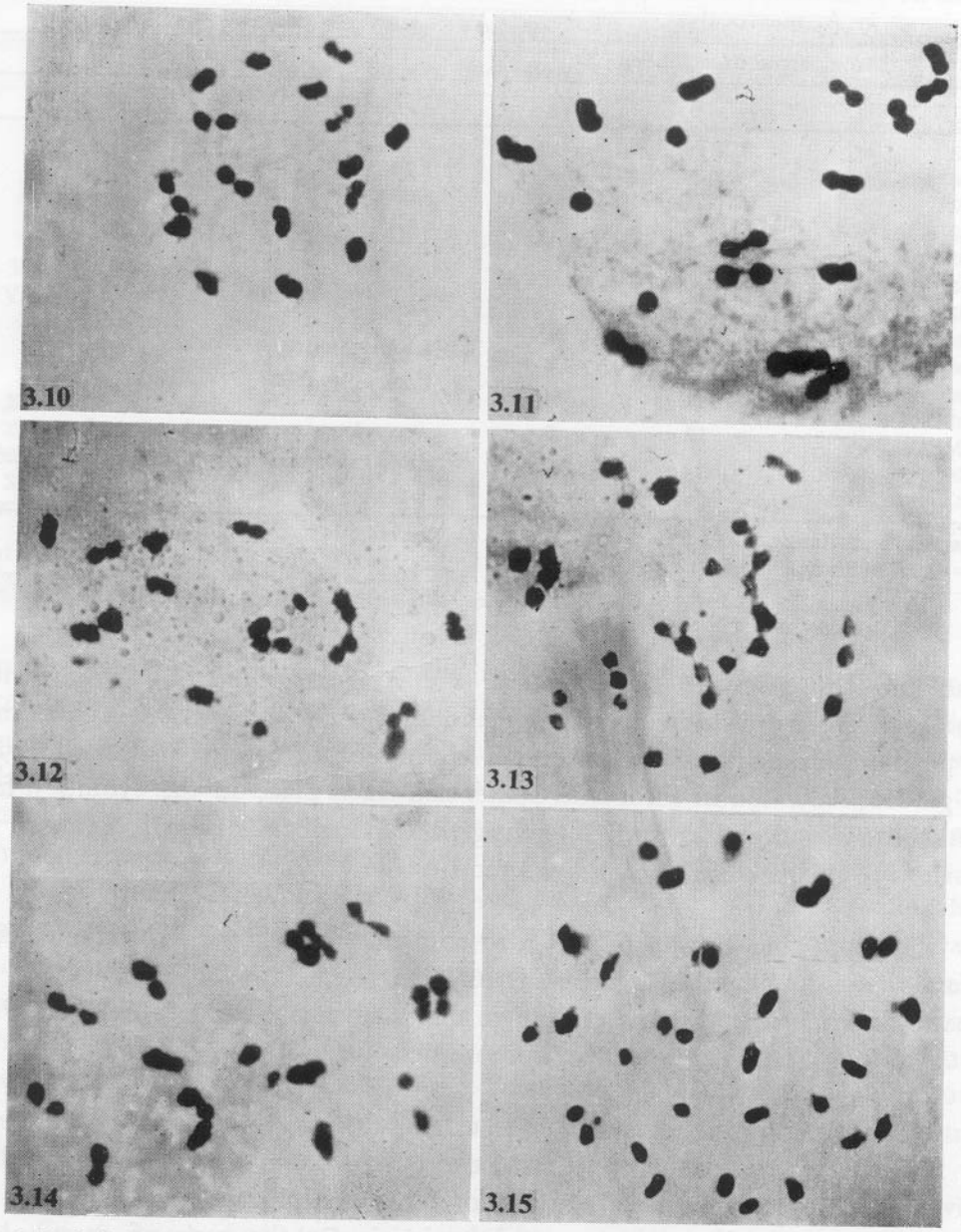
Meiotic observation in five palms belonging to *A. triandra* showed that maximum association of only bivalents occurs in palm No. 70 (Fig. 3.10), and trivalents (Fig. 3.11) and quadrivalents (Fig. 3.12) in the others (Table 3.1). The chromosome pairing in *A. catechu* × *A. triandra* hybrids showed a maximum association of one octovalent in hybrid No. 248 (Fig. 3.13), quadrivalent in hybrid No. 288 and spontaneous hybrid (Fig. 3.14) and trivalents in others (Table 3.1).

Partial desynapsis of chromosomes at diakinesis was reported by Bavappa (1974) and Bavappa and Nair (1978) in *A. triandra* and *A. catechu* × *A. triandra* hybrids. Desynapsis observed at diakinesis was followed by an increase in pairing at metaphase I as reflected by the frequency of bivalents (Table 3.1) in *A. triandra* and *A. catechu* × *A. triandra* hybrids and this was attributed to distributive pairing, a mechanism that has been possibly adopted for ensuring their regular segregation (Bavappa and Nair, 1978). The extent of desynapsis was higher in the F_1 hybrids of *A. catechu* and *A. triandra* (Fig. 3.15) as compared to *A. triandra,* suggesting that the gene controlling this character may be dominant. The large number of univalents observed in the hybrid as compared to *A. triandra* parent (Table 3.1) has been attributed to reduced homology of the parental chromosomes (Bavappa and Nair, 1978).

Nair and Ratnambal (1978) reported chromosome association in *A. macrocalyx* during microsporogenesis. While 16 bivalents were of the highest frequency at diakinesis and metaphase I, the maximum configuration observed was one hexavalent at both the stages of division (Table 3.4). The chromosome association in *A. macrocalyx* indicated the probability of autopolyploid origin with restricted multivalent formation as in the case of *A. catechu* and *A. triandra.*

3. Karyotype

Venkatasubban (1945) observed two pairs of short satellite chromosomes in the somatic chromosome complement of *A. catechu.* Three pairs of long chromosomes, six pairs of medium sized chromosomes and seven pairs of short chromosomes were observed by Sharma and Sarkar (1956) in *A. catechu.* They categorised the chromosomes into seven groups based on their morphology and relative length. Two pairs of long chromosomes next to the longest was found to have secondary constrictions. They also observed that the chromosomes of *A. triandra* were longer than those of *A. catechu.* Bavappa and Raman (1965)



Figs. 3.10—3.15 Microsporogenesis in *A. triandra* and *A. catechu* × *A. triandra* hybrids. *Fig. 3.10* A. triandra *Ceylon-3 (70), diakinesis 16 II; Fig. 3.11* A. triandra *Mauritius (109), M I, 1 III+13 II+ 3 I; Fig. 3.12* A. triandra *Ceylon-3 (87), diakinesis 1 IV + 13 II + 2 I; Fig. 3.13* A. catechu × A. triandra *(248), diakinesis 1 VIII + 1 V + 1 III + 5 II + 6 I; Fig. 3.14 Spontaneous hybrid, M1, 1 IV + 11 II + 6 I; Fig. 3.15* A. catechu × A. triandra *(287), diakinesis, 1 II + 30 I.*

Table 3.4. *Chromosome associations and their frequencies at diakinesis and metaphase I in* A. macrocalyx

Chromosome associations				Frequencies at	
VI	IV	II	I	Diakinesis	Metaphase I
1	—	13		5	3
	4	8		2	4
	3	10		2	3
	2	12		7	5
	1	14		17	9
		16		50	17
		15	2	6	8
		14	4	2	2
		13	6	1	6
				92	57

Average association :

Diakinesis : $0.05_{VI} + 0.49_{IV} + 14.73_{II} + 0.28_{I}$

Metaphase I : $0.05_{VI} + 0.77_{IV} + 13.83_{II} + 1.06_{I}$

found the chromosomes of *A. catechu* and *A. triandra* differing in size, total chromatin length, position of primary and secondary constrictions and number and position of satellites. Based on the assumption of Sharma and Sarkar (1956) that gradual reduction in chromatin matter had taken place in the evolution from primitive to advanced forms of different genera and tribe of Palmae, Bavappa and Raman (1965) considered *A. catechu* as more advanced than *A. triandra.*

Bavappa and Raman (1965) also studied the pachytene chromosomes in *A. catechu* and found morphological features in fairly close agreement with the somatic chromosomes (Table 3.5), though the pachytene chromosomes were about ten times longer than the somatic chromosomes.

The chromosome morphology of a few cultivars of *A. catechu* from Assam was reported by Raghavan (1957). Minor variation in structure and length of individual chromosomes, total length of the complement and position of constrictions among the types was noted by him. On the basis of morphology, he recognised nine groups in the somatic chromosomes of the cultivars.

Studies on the karyotypes of eight cultivars of *A. catechu* and four ecotypes of *A. triandra* (Bavappa, 1974; Bavappa, Nair and Ratnambal, 1975) revealed

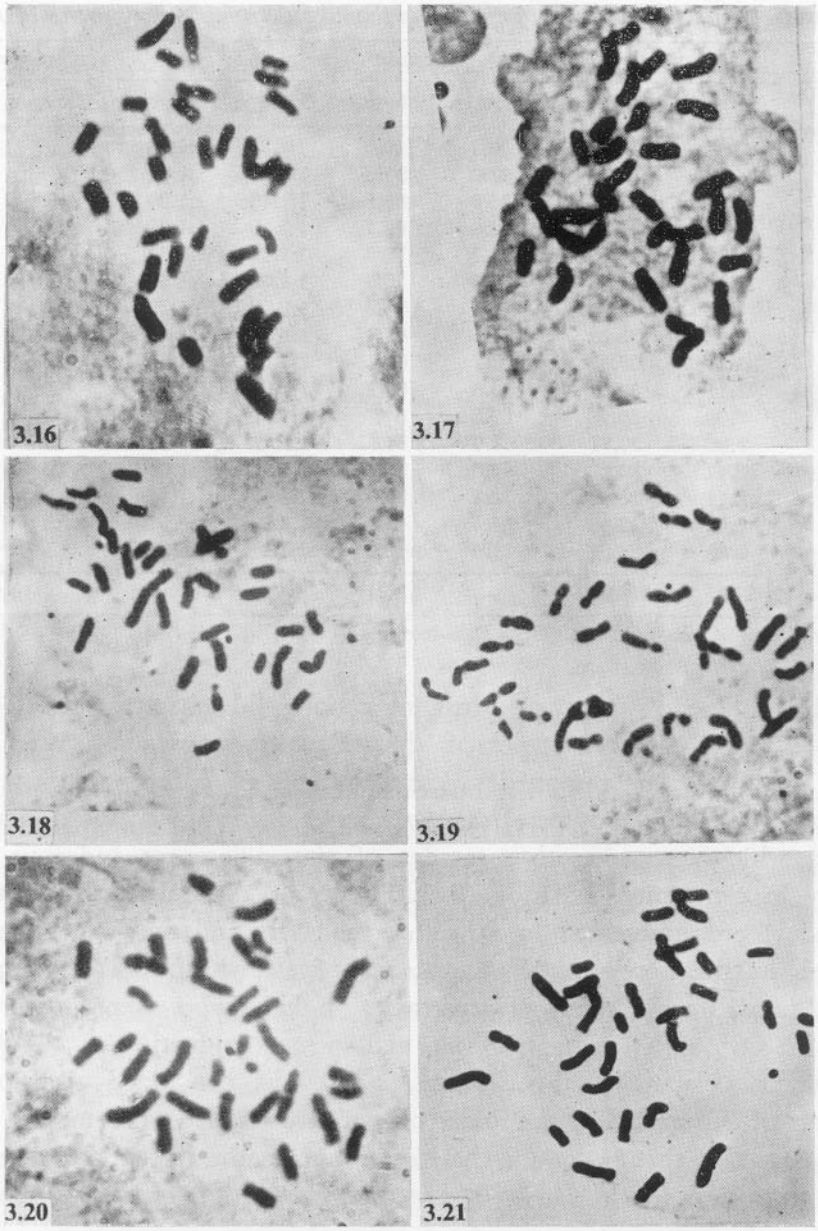
Table 3.5. *Comparative analysis of the somatic and pachytene chromosomes of* A. catechu

Chromosome	Length in μ		Relative length		Arm ratio		Centromere position	
	Somatic	Pachytene	Somatic	Pachytene	Somatic	Pachytene	Somatic	Pachytene
I	4.41	56.63	100.0	100.0	1:1.20	1:1.33	M	Sm
II	4.28	53.89	97.0	95.2	1:1.46	1:1.40	Sm	Sm
III	4.17	49.91	94 5	88.1	1:1.45	1:1.09	Sm	M
IV	3.89	46.86	88.2	82.7	1:2.19	1:1.35	St	Sm
V	3.78	46.00	85.7	75.9	1:1.29	1:1.54	Sm	Sm
VI	3.41	42.63	77.3	75.5	1:2.09	1:4.26	St	St
VII	3.31	42.04	75.1	74.2	1:2.09	1:1.79	St	Sm
VIII	3.28	39.00	74.4	68.9	1:1.88	1:1.45	Sm	Sm
IX	3.21	36.36	72.7	64.2	1:1.83	1:1.25	Sm	M
X	3.11	34.31	70.5	60.2	1:1.83	1:2.21	Sm	St
XI	3.06	30.99	69.3	54.7	1:1.78	1:1.45	Sm	Sm
XII	2.80	30.77	63.5	54.3	1:1.62	1:2.76	Sm	St
XIII	2.47	30.22	56.0	53.4	1:1.11	1:1.04	M	M
XIV	2.44	28.49	56.3	50.3	1:1.87	1:1.14	Sm	M
XV	2.40	25.63	54.4	45.3	1:3.00	1:3.50	St	St
XVI	2.29	22.67	51.9	40.0	1:1.31	1:3.02	Sm	St
Total :	52.31	616.40	—	—	—	—	—	—

M = Median; Sm = Sub-median; St = Sub-terminal

considerable differences in their gross morphological characteristics (Figs.3.16–3.42; Table 3.6). The karyotypes of the *A. triandra* ecotypes showed a higher frequency of submedian and median chromosomes as compared to *A. catechu*. A classification of the karyotype of the two species according to the degree of their asymmetry which recognises three grades of size differences and four grades of asymmetry in centromere position (Stebbins, 1958), showed that karyotypes, 1B, 2A, 2B and 3B are represented in *A. catechu* cultivars and only 1A, 2A and 2B are represented in the ecotypes of *A. triandra*. Even within the same cultivar of *A. catechu*, two different types of asymmetry in karyotypes were observed, while there was no such variation in *A. triandra* ecotypes. Evidently *A. triandra* has a more symmetrical karyotype than *A. catechu*. It was concluded that delineating the cultivars of *A. catechu* on the basis of standard karyotype seemed to be rather difficult. The fact that *A. catechu* has lesser chromatin matter and asymmetrical karyotype compared to *A. triandra* shows that the latter is more primitive.

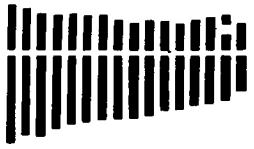
In *A. catechu* and *A. triandra* the relative length of chromosomes ranged from 4.12 to 8.59 whereas in the *A. catechu* × *A. triandra* hybrids the variation was from 3.45 to 10.72 (Table 3.7). This indicated that compensation effect due to differential dimensions of the parental chromosomes has brought about a reduction in the length of the shortest chromosome and an increase in that of the longest



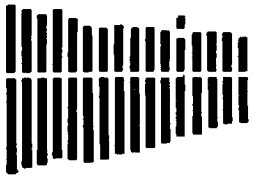
Figs. 3.16—3.21 Somatic chromosomes in *Areca* spp. and hybrids. *Fig. 3.16* A. catechu *Local (717), 2n=32; Fig. 3.17* A. catechu *China (111), 2n=32; Fig. 3.18* A. triandra *Indonesia-2 (154), 2n=32; Fig. 3.19* A. triandra *Ceylon-3 (87), 2n=32; Fig. 3.20* A. catechu × A. triandra *(248), 2n=32; Fig. 3.21* A. catechu × A. triandra *(307), 2n=32.*

3.22

3.23



3.24



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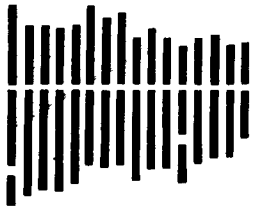
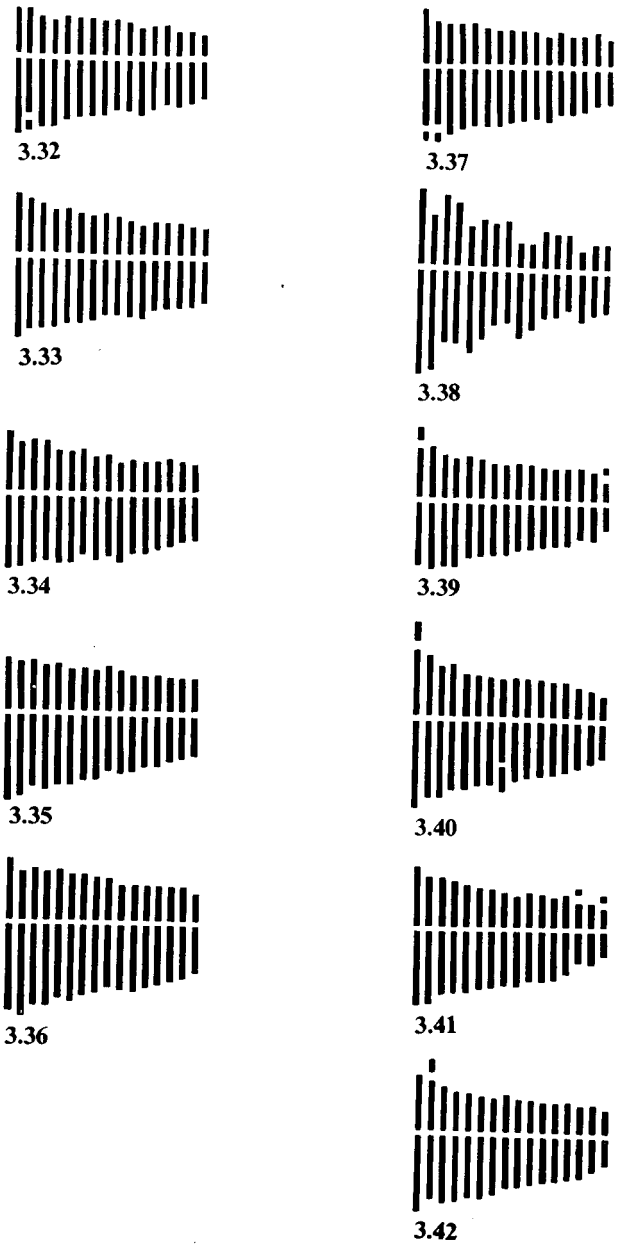


3.31

Fig. 3.22—3.31 Idiograms of *A. catechu* and *A. triandra*. *Fig. 3.22* A. catechu *Local (471); Fig. 3.23* A. catechu *Local (717); Fig. 3.24* A. catechu *China (111); Fig. 3.25* A. catechu *Ceylon-1 (191); Fig. 3.26* A. catechu *Indonesia (6); Fig 3.27* A. catechu *Saigon-1 (176); Fig. 3.28* A. catechu *Saigon-2 (180); Fig. 2.29* A. catechu *Ceylon-2 (192); Fig. 3.30* A. catechu *Singapore (163); Fig. 3.31* A. triandra *Mauritius (109).*



Figs. 3.32—3.42 Idiograms of *A. triandra* and *A. catechu*×*A. triandra* hybrids. *Fig. 3.32* A. triandra *Indonesia-1 (125); Fig. 3.33* A. triandra *Indonesia-2 (74); Fig. 3.34* A. triandra *Indonesia-2 (154); Fig. 3.35* A. triandra *Ceylon-3 (55); Fig. 3.36* A. triandra *Ceylon-3 (70); Fig. 3.37* A. triandra *Ceylon-3 (87); Fig. 3.38* A. catechu×A. triandra *(248); Fig. 3.39* A. catechu× A. triandra *(287); Fig. 3.40* A. catechu×A. triandra *(288); Fig. 3.41* A. catechu× A. triandra *(307); Fig. 3.42* A. catechu×A. triandra *Spontaneous hybrid.*

Table 3.6. *Karyotype differences in* A. catechu, A. triandra *and their hybrids*

Species/hybrids	2n	Total chromatin length (μ)	Range of chromosome length (μ)	Chromosome types			Satellite chromosome	Symmetry (Stebbins, 1958)
				Median	Sub-median	Sub-terminal		
A. catechu								
Local (471)	32	49.42	4.13–2.18	–	6	10	3	2A
Local (717)	32	43.97	3.78–1.83	5	11	–	–	1B
China (111)	32	41.64	3.59–1.72	–	1	15	1	3B
Ceylon-1 (191)	32	51.79	4.41–2.14	5	9	2	1	1B
Indonesia-6 (61)	32	46.81	4.12–1.93	–	3	13	1	2B
Saigon-1 (176)	32	44·48	3.67–1.92	–	9	7	1	2A
Saigon-2 (180)	32	50.78	4.15–2.13	–	3	13	1	2A
Ceylon-2 (192)	32	47.60	4.43–1.88	–	3	13	1	3B
Singapore (163)	32	44.52	3.62–2.11	–	6	10	2	2A
A. triandra								
Mauritius (109)	32	61.21	5.24–2.52	4	3	9	2	2B
Indonesia-1 (125)	32	48.04	4.04–2.02	–	9	7	1	2B
Indonesia-2 (74)	32	53.73	4.68–2.40	2	8	6	–	2A
Indonesia-2 (154)	32	54.14	4.41–2.44	3	7	6	–	2A
Ceylon-3 (55)	32	56.32	4.72–2.46	1	10	5	–	1A
Ceylon-3 (70)	32	59.77	4.89–2.62	–	11	5	–	1A
Ceylon-3 (87)	32	50.59	4.20–2.14	3	12	1	2	1A
A. catechu × *A. triandra*								
Palm No. (248)	32	56.80	6.19–2.21	6	4	6	–	2B
Palm No. (287)	32	47.35	4.20–1.68	9	7	–	2	1B
Palm No. (288)	32	55.88	5.77–1.99	2	11	3	2	2B
Palm No. (307)	32	48.69	4.51–1.68	5	10	1	2	1B
Spontaneous hybrid	32	48.19	4.43–1.83	2	12	2	1	1B

Table 3.7. *Chromosome frequencies of* A. catechu, A. triandra *and interspecific hybrids in different relative length classes*

Species/hybrids	10.9	10.4	9.9	9.4	8.9	8.4	7.9	7.4	6.9	6.4	5.9	5.4	4.9	4.4	3.9	3.4
A. catechu																
Local (471)	–	–	–	–	–	1	1	3	2	3	2	2	2	–	–	
Local (717)	–	–	–	–	1	–	2	2	2	2	2	2	2	1	–	
China (111)	–	–	–	–	1	–	2	2	1	4	2	2	1	1	–	
Ceylon-1 (191)	–	–	–	–	1	1	2	1	3	1	2	2	2	1	–	
Indonesia-6 (61)	–	–	–	–	1	–	2	2	2	2	3	2	1	1	–	
Saigon-1 (176)	–	–	–	–	–	1	2	1	3	3	2	2	1	1	–	
Saigon-2 (180)	–	–	–	–	–	1	2	2	2	3	2	2	1	1	–	
Ceylon-2 (192)	–	–	–	2	1	1	1	1	1	1	1	3	2	2	–	
Singapore (163)	–	–	–	–	–	1	1	2	3	3	3	2	1	–	–	
A. triandra																
Mauritius (109)	–	–	–	–	–	1	1	2	4	2	4	–	1	1	–	
Indonesia-1 (125)	–	–	–	–	1	–	2	2	2	3	2	2	1	1	–	
Indonesia-2 (74)	–	–	–	–	1	–	2	2	1	3	3	2	2	–	–	
Indonesia-2 (154)	–	–	–	–	–	1	2	2	2	3	2	2	1	1	–	
Ceylon-3 (55)	–	–	–	–	–	1	2	2	2	2	3	3	–	1	–	
Ceylon-3 (70)	–	–	–	–	–	1	2	2	2	2	3	3	–	1	–	
Ceylon-3 (87)	–	–	–	–	–	1	1	1	2	3	4	2	1	1	–	
A. catechu×*A. triandra*																
Palm No. (248)	1	–	–	1	1	1	–	1	1	2	2	1	2	2	1	
Palm No. (287)	–	–	–	2	–	–	2	1	1	2	3	2	2	–	1	
Palm No. (288)	–	1	–	–	1	–	1	1	2	3	2	2	1	1	1	
Palm No. (307)	–	–	–	1	1	1	1	1	2	1	4	1	–	2	1	
Spontaneous hybrid	–	–	–	1	1	–	1	2	2	2	2	2	2	–	1	

chromosome. No consistency in the presence/absence, the number and position of satellites could be observed either in the parents or hybrids. It was inferred that in the classification of the karyotypes in *Areca* species, satellite may have only limited role.

4. Basic number

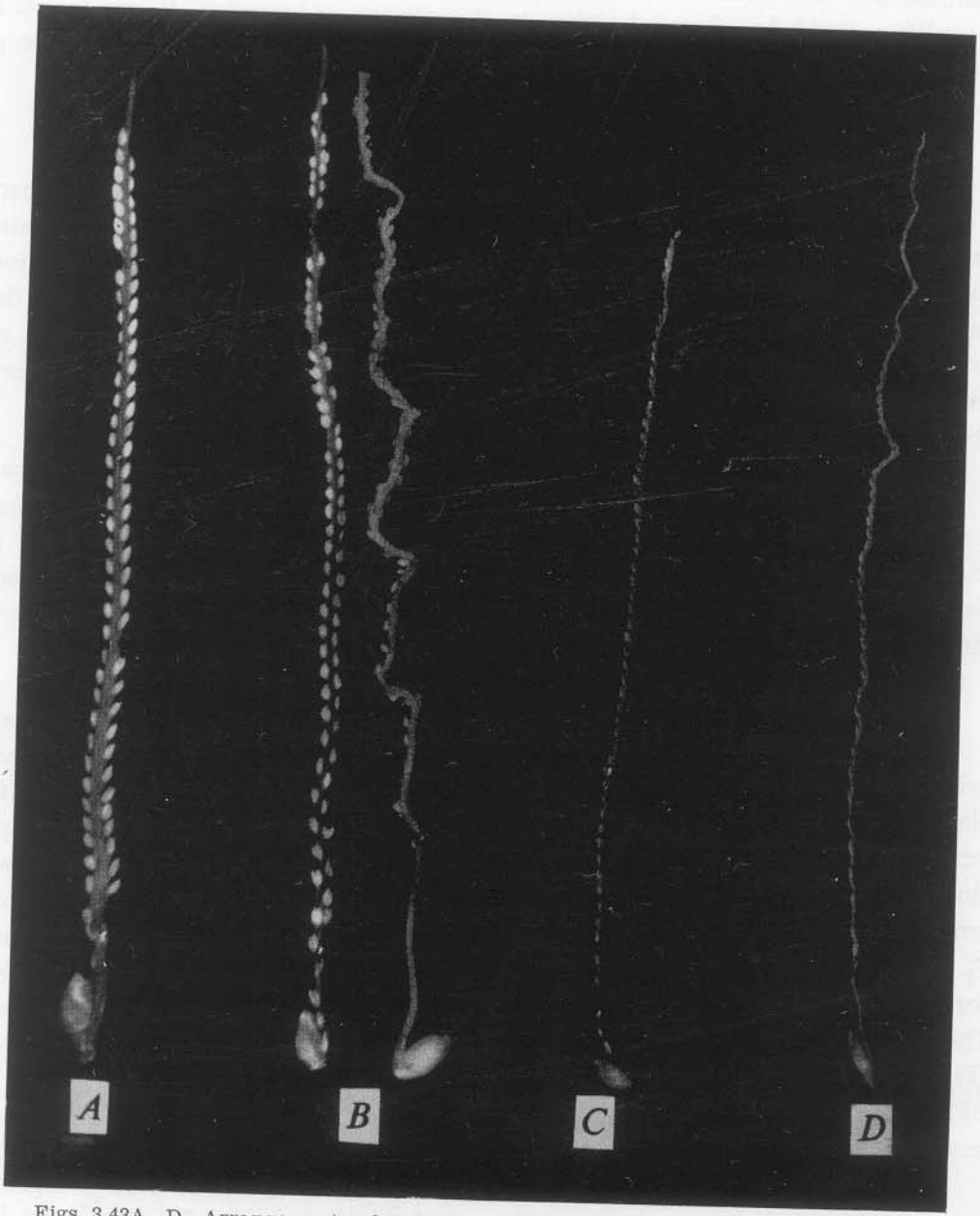
Based on the cytogenetical studies on different genera of Palmae, Venkatasubban (1945) suggested a basic number of x=8 and secondary basic numbers of x=7 and 9, derived from x=8 by fusion and fragmentation respectively. Darlington and Janaki Ammal (1945) proposed x=16 as the basic number for *Areca*. Sharma and Sarkar (1956) stressed the role of amphidiploidy in the initial stages of evolution of the tribe *Areceae* and deduced a basic number of x=8 for the tribe.

A basic number of x=7 was assumed for *Areca* by Bavappa and Raman (1965) based on the secondary association and karyomorphological data. They could recognise seven groups in the chromosome complement of *A. catechu* as distinguished by the length and morphology of somatic as well as pachytene chromosomes and concluded that *A. catechu* is a secondary allotetraploid.

5. Apomixis

Bavappa and Nair (1975) reported morphological differences in reciprocal hybrids between *A. catechu* and *A. triandra*. All the *A. triandra* × *A. catechu* plants showed considerable morphological similarities with the female parent for stem number, internodal distance, stem girth at fixed mark, leaf number per clump, female flower size, number and size of male flowers, male flower arrangements (Figs. 3.43 A-D) and maturity period of fruits (Table 3.8). While F_1 of *A. catechu* × *A. triandra* showed clear evidences for heterosis and dominance for certain characters, the reciprocal hybrids did not show such genetic effect. These, along with the differences in F_0 nuts observed in the reciprocal crosses (Fig. 3.44; Table 3.9), and failure of *A. catechu* pollen to germinate on the stigma of *A. triandra* indicated that *A. triandra* × *A. catechu* nuts (F_0) might not be of sexual origin.

Apomictic reproduction in *A. triandra* was indicated by the limited degree of meiotic irregularities, reduced pollen fertility, low quantity of pollen, and low chiasma frequency in the species(Bavappa, 1974), together with morphological and genetical evidences obtained from the reciprocal crosses. The observation that *A. catechu* pollen failed to germinate on the stigma of *A. triandra* and fruit set



Figs. 3.43A—D Arrangements of male flowers on the rachis. *A.* A. catechu—*single biseriate and alternate;* *B.* A. catechu × A. triandra—*pairs, biseriate and alternate;* *C.* A. triandra × A. catechu—*pairs, uniseriate;* *D.* A. triandra—*pairs, uniseriate.*

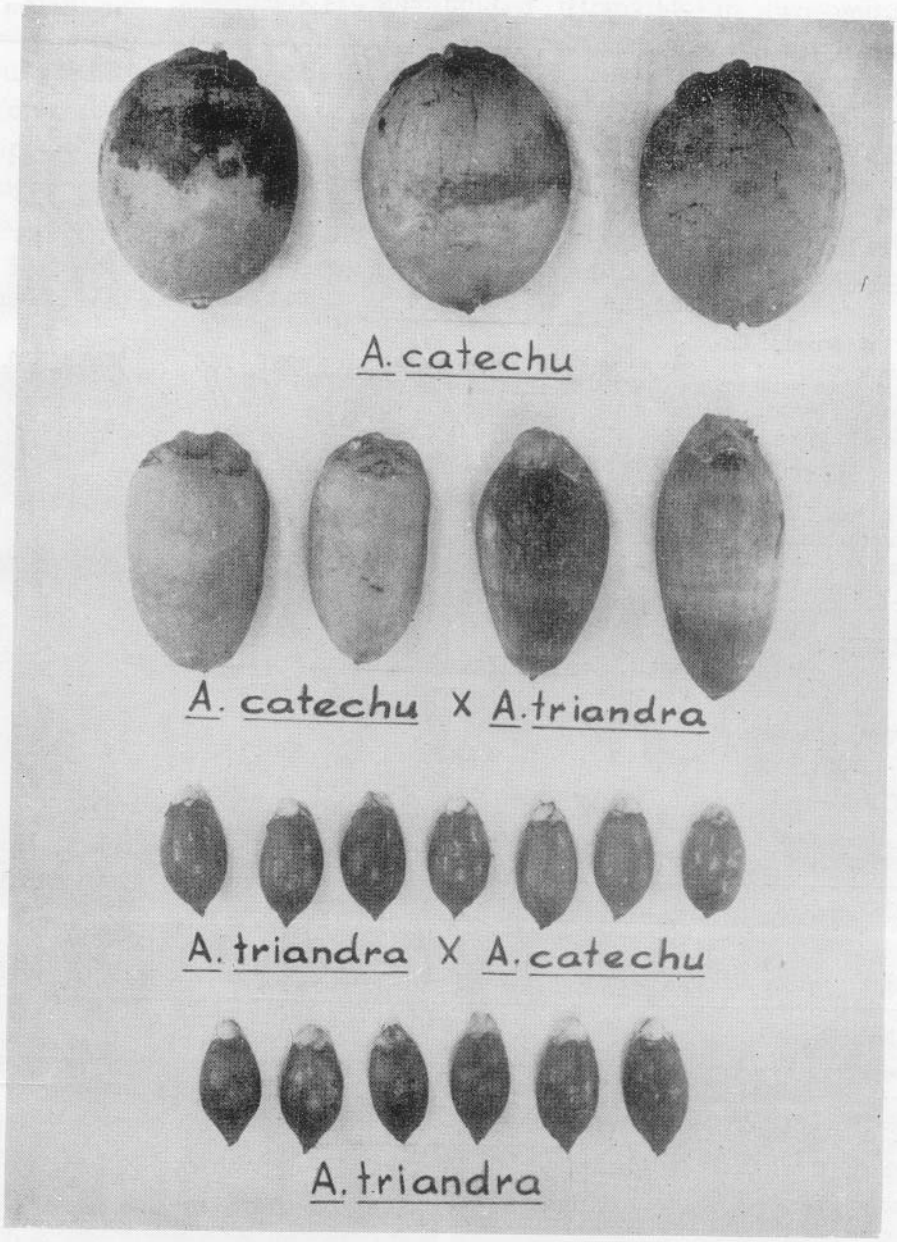


Fig. 3.44 Ripe nuts in *A. catechu*, *A. catechu* × *A. triandra* F_0, *A. triandra* × *A. catechu* F_0 and *A. triandra*

Table 3.8. *Morphological characteristics of* A. catechu, A. triandra *and their hybrids*

Characters	*A. catechu*	*A. catechu* × *A. triandra*	*A. triandra* × *A. catechu*	*A. triandra*
Number of stems	1	1	9.5±3.1	9.8±2.9
Internodal distance at fixed mark (cm)	11.4±3.3	19.8±2.4	16.0±1.7	13.6±3.6
Girth of stem at fixed mark (cm)	45.3±4.4	39.0±0.70	24.1±0.4	18.2±1.2
Number of leaves/clump	9.5±0.3	9.5±0.3	35.0±3.4	51.4±14.4
Mean length of spadix (cm)	56.3±2.9	87.8±2.6	50.3±1.2	43.0±2.3
Number of female flowers/bunch	386.3±36.4	2856.8±340.3	409.8±64.6	588.2±133.4
Mean length × breadth of female flowers (cm)	1.76×1.02	1.13×0.52	0.83×0.05	0.84×0.46
Number of male flowers/bunch	33521±5080	48856±3868	29682±4027	27083±3191
Mean length × breadth of male flowers (cm)	0.44×0.23	0.26×0.12	0.24×0.10	0.22×0.10
Number of stamens	6, occasionally 5	3–5	3	3
Arrangement of male flowers	Single, biseriate, alternate	Paired, biseriate, alternate	Paired, uniseriate	Paired, uniseriate
Mean length × breadth of fruit (cm)	5.3×4.2	4.2×2.1	2.9×1.44	2.7×1.5
Maturity period of nuts (days)	287±16	298±19	162±1	163±8
Pollen stainability	93.0±3.5	4.7±1.7	67.0±6.4	56.5±7.6

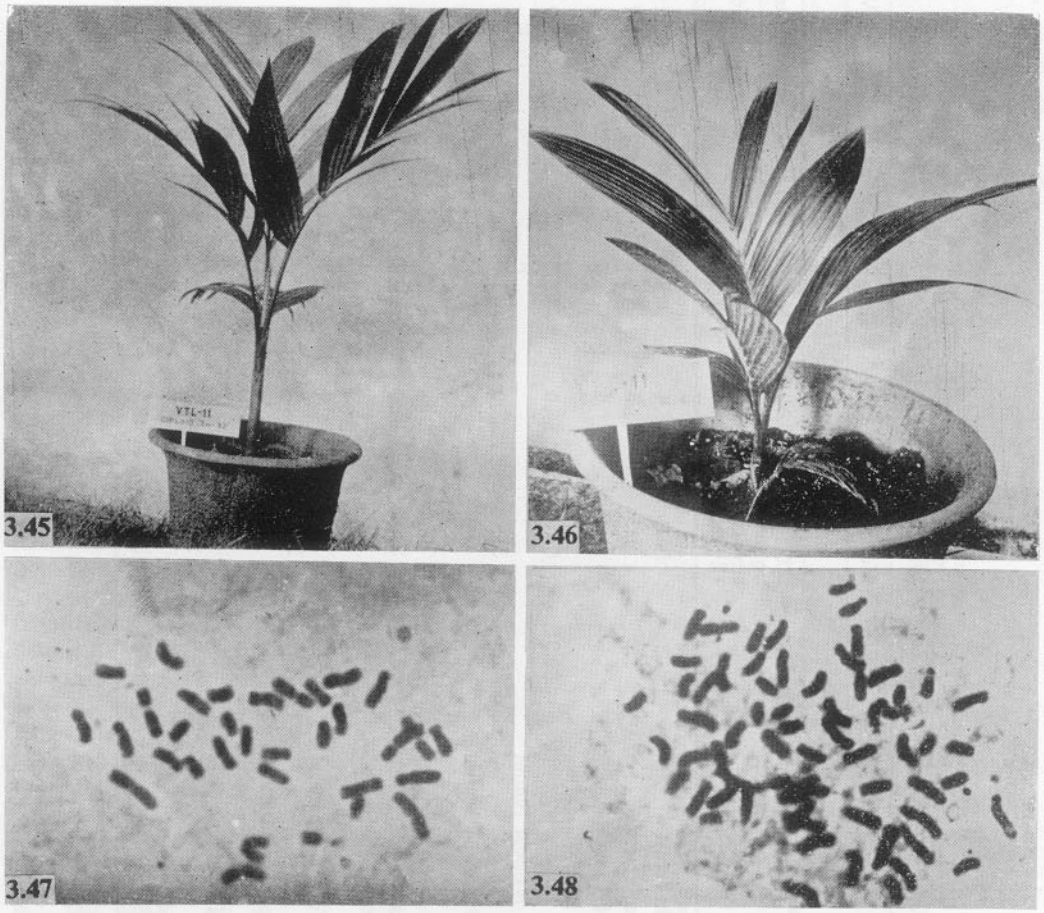
Table 3.9. *Mean size and weight of nuts of* A. catechu, A. triandra *and their hybrids* (F_0)

Parents/hybrids	Length (cm)	Breadth (cm)	Weight (gm)
A. catechu	5.3	4.2	43.6
A. catechu × *A. triandra* (F_0)	5.5	3.3	34.2
A. triandra × *A. catechu* (F_0)	2.7	1.5	3.9
A. triandra	2.7	1.5	3.9

obtained without pollination in *A. triandra* and *A. triandra* × *A. catechu* showed that apomixis in *A. triandra* is autonomous (Bavappa, 1974; Bavappa and Nair, 1975).

6. Induced polyploidy

Nair and Ratnambal (1974) induced tetraploids in two cultivars of *A. catechu, Mangala* and VTL–11 (Indonesia) by treating the emerging sprouts with aqueous colchicine. Two tetraploids in *Mangala* and five in VTL–11 were isolated based on chromosome counts in somatic cells; the most successful treatment being the dipping of sprouts in 0.1% aqueous colchicine for 24 hr. The tetraploid seedlings were stunted in growth compared to the diploids, and had reduced plant height and number, length and breadth of leaves (Figs. 3.45, 3.46, 3.47 and 3.48; Table 3.10). The tetraploids had fewer epidermal cells and stomata per unit area.



Figs. 3.45—3.48 Diploids and tetraploids in *A. catechu*. *Fig. 3.45* A. catechu *(VTL–11) diploid plant; Fig. 3.46* A. catechu *(VTL–11) tetraploid plant; Fig. 3.47 Somatic chromosomes in diploid plant (VTL–11) 2n=32; Fig. 3.48 Somatic chromosomes in tetraploid plant (VTL–11) 4n=64.*

Table 3.10. *Morphological and anatomical characters of diploids and tetraploids in* A. catechu *(Nine months old seedlings)*

Characters	*Mangala*			VTL – 11					
		Tetraploids			Tetraploids				
	Diploid	0.1% aqueous colchicine 24 hr.	0.5% aqueous colchicine 72 hr.	Diploid	0.1% aqueous 24 hr.		0.1% aqueous colchicine 72 hr.	0.2% aqueous colchicine 48 hr.	0.5% aqueous colchicine 72 hr.
					Plant No.1	Plant No.2			
Plant height (cm)	116.5	80.0	65.5	28.5	28.5	92.5	61.0	65.0	61.5
Girth at collar (cm)	1.6	1.8	1.4	1.8	0.7	1.7	1.3	2.1	1.6
Number of leaves	6	4	4	6	3	4	4	6	5
Length of longest leaf (cm)	69.5	61.5	53.0	76.5	25.5	75.0	51.0	45.0	27.0
Length of longest leaflet (cm)	36.5	31.0	27.0	37.0	–	38.0	30.5	26.5	26.5
Breadth of middle leaflet (cm)	4.1	5.4	3.3	6.4	–	5.4	5.0	3.1	7.4
Number of epidermal cells/unit area	43.0	32.4	37.2	43.0	–	43.2	26.3	39.4	39.9
Length of epidermal cells (μ)	46.9	57.0	56.6	45.8	–	47.2	69.7	59.6	58.1
Breadth of epidermal cells (μ)	21.1	22.9	23.1	18.6	–	21.6	20.5	22.7	21.3
Number of stomata/unit area	3.5	2.6	2.7	3.3	–	3.3	2.3	2.6	2.3
Length of guard cells (μ)	29.9	35.3	31.0	28.3	–	34.5	35.6	27.4	27.8
Breadth of guard cells (μ)	10.5	13.0	12.8	10.3	–	13.1	12.9	13.9	10.6

II. Breeding

Crop improvement work in arecanut has been mainly through introductions of exotic and indigenous types and refinements of selection procedures in mother palms, seednuts and seedlings, though hybridisation has also been undertaken in recent years.

1. Introduction

A collection of the cultivars of *A. catechu* and related species from within the country as well as from Sri Lanka, the Philippines, Indonesia, Singapore, Malaysia, Thailand, South China, Fiji, Solomon Islands and Mauritius are being maintained at the Regional Station, Vittal of the Central Plantation Crops Research Institute. The exotic collection consisting of six species of *Areca* (Figs. 3.49, 3.50, 3.51 and 3.52) and 34 *A. catechu* cultivars were introduced in various stages, starting from 1957. The comparative yield evaluation of 16 types among these for a period of nine years (1964–'65 to 1972–'73) indicated that five introductions *viz.*, VTL–3 (China), VTL–11 (Indonesia), VTL–12 and VTL–13 (Thailand), and VTL–17 (Singapore) have high yield potential and the increase in yield (weight of nuts) was 6–50% more than the local cultivar (Table 3.11) (Anonymous, 1974).

Table 3.11. *Yield (weight of nuts) of 16 exotic introductions of* A. catechu

Name of the type	Accession number	1964–1965 to 1972–1973 (Average for 9 years)	Percentage of increase (+) or decrease (—) over Local
		Wet weight of nuts per tree in kg.	
Fiji	VTL–1	3.1	—68.0
Mauritius	VTL–2	6.1	—37.1
China	VTL–3	10.3	+ 6.2
Ceylon–1	VTL–5	6.9	—28.9
Indonesia–1	VTL–6	1.4	—85.6
Indonesia–2	VTL–7	8.2	—15.5
Ceylon–2	VTL–15	6.7	—30.9
Indonesia–6	VTL–11	14.5	+49.5
Saigon–1	VTL–12	12.9	+33.0
Saigon–2	VTL–13	11.7	+20.6
Saigon–3	VTL–14	9.0	— 7.2
Singapore	VTL–17	14.6	+50.5
Solomon Islands–1	VTL–18a	2.7	—72.2
Solomon Islands–2	VTL–18b	5.1	—47.4
Solomon Islands–3	VTL–18c	3.2	—67.0
Ceylon–3	VTL–21	2.6	—73.2
South Kanara (control)	—	9.7	—
S.E. per plot		3.9	
Overall mean		7.6	
C. V. (%)		52.0	
C. D. (P=0.05)		4.5	

Fig. 3.49—3 52 *Areca* species and related genus. *Fig. 3.49* A. triandra; *Fig. 3.50* A. normanbyii; *Fig. 3.51* A. macrocalyx; *Fig. 3.52* Actinorhytis calapparia.

Fig. 3.53 *Mangala*

Among these accessions, VTL–3 obtained from Peking (China) was found to have a number of desirable characters such as earliness in bearing, more number of female flowers per inflorescence, higher nut set, initial and cumulative higher yields, quicker stabilisation of production and lower height, in comparison with the Local ('South Kanara') cultivar (Table 3.12).

Table 3.12. *Comparative yield of* Mangala *(1967 planting)*

Cultivars	Wet weight of nuts/palm/year						
	1970–'71	1971–'72	1972–'73	1973–'74	1974–'75	1975–'76	Total
Mangala	–	4.73	16.75	12.36	16.04	14.15	64.03
South Kanara	–	1 57	4.80	5.11	6.62	8.89	26.99

The cultivar has since been released under the name *Mangala* (Fig. 3.53). This semi–tall variety is characterised by partially drooping crown with well-spread leaves and having more number of leaflets than the local type. The leaflets are dark green in colour with crinkling at the tip. The fruits are dark green with good chewing and marketing quality of the nut (Bavappa, 1977).

The indigenous collections of *A. catechu* maintained at Vittal include 13 cultivars from Thirthahalli, Chickamagalur, Hirehalli, Peechi, Mohitnagar, Assam, South Kanara and Gujarat planted in 1964, and four more types from Sreevardhan, Dapoli, Thirthahalli and Assam planted during 1966. In addition, four progenies of a dwarf palm from Thirthahalli are also being maintained (Fig. 3.54).

Yield evaluation of the seven cultivars among these (introduced in 1964) for a period of ten years (1967–'76) showed continued high yield of 'Thirthahalli' over others. There was no significant difference in yield in the case of other cultivars in comparison with the 'South Kanara' type (Table 3.13).

2. Selection

i. *Seedling selection*

Studies on selection of arecanut seedlings showed that considerable increase in yield of the plantation could be obtained by judicious selection of seedling at the time of planting, as well as in subsequent stages (Bavappa and Ramachander, 1967a, Bavappa, 1970).

It has been established that in the case of seedlings, number of leaves at the time of planting, girth at collar one year after planting and number of nodes two years after planting have high heritability and have positive genotypic and

Fig. 3.54 Dwarf mutants of *A. catechu*

Table 3.13. *Yield (weight of nuts) of seven indigenous cultivars of* A. catechu

Cultivar	Wet weight of nuts/tree/year in kg										Mean yield	Percentage increase (+) or decrease (—) over local
	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976		
Thirthahalli	4.9	17.4	13.1	17.9	19.7	18.9	15.3	15.3	15.5	20.5	15.85	+49.1
Chickamagalur	3.8	8.3	8.0	9.2	5.4	8.5	4.5	6.1	7.6	8.3	6.97	—34.4
Hirehalli	2.9	13.9	9.2	13.9	17.1	10.8	16.9	12.7	9.4	13.7	12.10	+13.8
Peechi	3.5	8.8	7.6	10.7	15.6	10.2	9.6	13.1	13.3	6.7	9.91	— 6.8
Mettupalayam	2.6	8.9	10.0	10.1	12.9	5.0	12.1	5.1	6.2	7.4	8.03	—24.5
Mohitnagar	3.0	16.4	13.5	18.9	17.2	10.5	10.5	10.7	7.9	10.2	11.88	+11.6
Assam	3.1	14.6	4.9	9.6	-	6.3	-	6.3	6.3	5.9	7.12	—33.0
South Kanara (Control)	1.2	7.3	6.4	10.9	8.7	11.3	11.5	16.0	18.1	14.9	10.63	— -

phenotypic correlations with the yield. The yield behaviour of the palms selected under different groups for the above mentioned three characters showed that the best seedlings are those which have more than four leaves at the time of planting, and a girth of more than 20 cm after one year, and four nodes or more after two years of growth in the field after transplanting. Further, the negative correlation established for these three characters with age at first bearing indicated that excercising selection of seedlings for the above mentioned characters would aid in bringing down the age at first bearing of the population (Bavappa and Ramachander, 1967a, 1967c).

In view of the significant positive genotypic correlation of number of leaves and negative correlation of the height at the time of transplanting with subsequent yield, Bavappa (1970) suggested selection of seedlings having maximum number of leaves and minimum height. To simplify the procedure of selection, he suggested that the number of leaves present at the time of planting is to be multiplied by 40 and the height of the concerned plant substracted from this figure. Seedlings which have a high value for this alone should be selected (*e.g.*, No. of leaves=5, height of the plant=90 cm, no. of leaves $\times$ 40—height= $5 \times 40 - 90 = 110$. Suppose the value of the seedlings vary from 50 to 150, seedlings having higher values may be selected to the extent practically feasible).

ii. *Mother palm selection*

Bavappa and Ramachander (1967c) tested the validity of the earlier method of selection of seed material as a means of genetic improvement which consisted of collection of seeds from phenotypically high yielding mother palms located in gardens reputed for their average yield (Bavappa, Patel and Mohiyuddin, 1958). The progeny performance as judged from the yield of 41 such mother palms (Table 3.14) showed that though the mother palms had been selected for

Table 3.14. *Frequency distribution of mother palms based on progeny performance*

Range in mean yield of progency (gm)	No. of mother palms	
	1963–'64	1964–'65
2000–3000	3	0
3000–4000	8	2
4000–5000	7	7
5000–6000	11	11
6000–7000	7	11
7000–8000	6	6
8000–9000	2	3
9000–10000	0	1

high yield, there was wide variability in the performance of their progenies. It was also observed that the mother palms having high progeny performance were present in all the gardens more or less uniformly and there was no advantage in selection of mother palms giving stress to the garden in which they are located. They also observed that the progeny performance had no relation with the regularity in the yielding behaviour of mother palms (Bavappa and Ramachander, 1967b; Anonymous, 1969a).

An examination of the yield pattern of palms of different bearing ages by Bavappa and Ramachander (1967c) showed that palms which came to bearing early are consistantly better yielders (Fig. 3.55; Table 3.15). Based on the data, they suggested that confining selection of seednuts to 62 per cent palms which come to bearing at fifth year, an increase in yield of 8–15 per cent could be expected depending upon the extent of selfing or nature of crossing taking place.

Table 3.15. *Yield pattern of palms having different age at first bearing*

Age at first bearing in years	Percentage of palms in the population	Yield (number of nuts) in different years				Mean
		I	II	III	IV	
5	62	109	211	255	305	220
6	32	–	139	148	208	165
7	4	–	–	58	95	76
8	1	–	–	–	34	34
9	1	–	–	–	–	0

Further, it was observed that selection of seedlings for number of leaves, girth at collar and number of nodes at the appropriate stage totally eliminated the late bearing palms and accordingly the yield of the population was increased (Table 3.16).

Table 3.16. *Effect of selection of seedlings on age at first bearing*

Age at first bearing in years	Percentage of palms in different age groups	
	Before selection	After selection
5	62	74
6	32	25
7	4	1
8	1	0
9	1	0

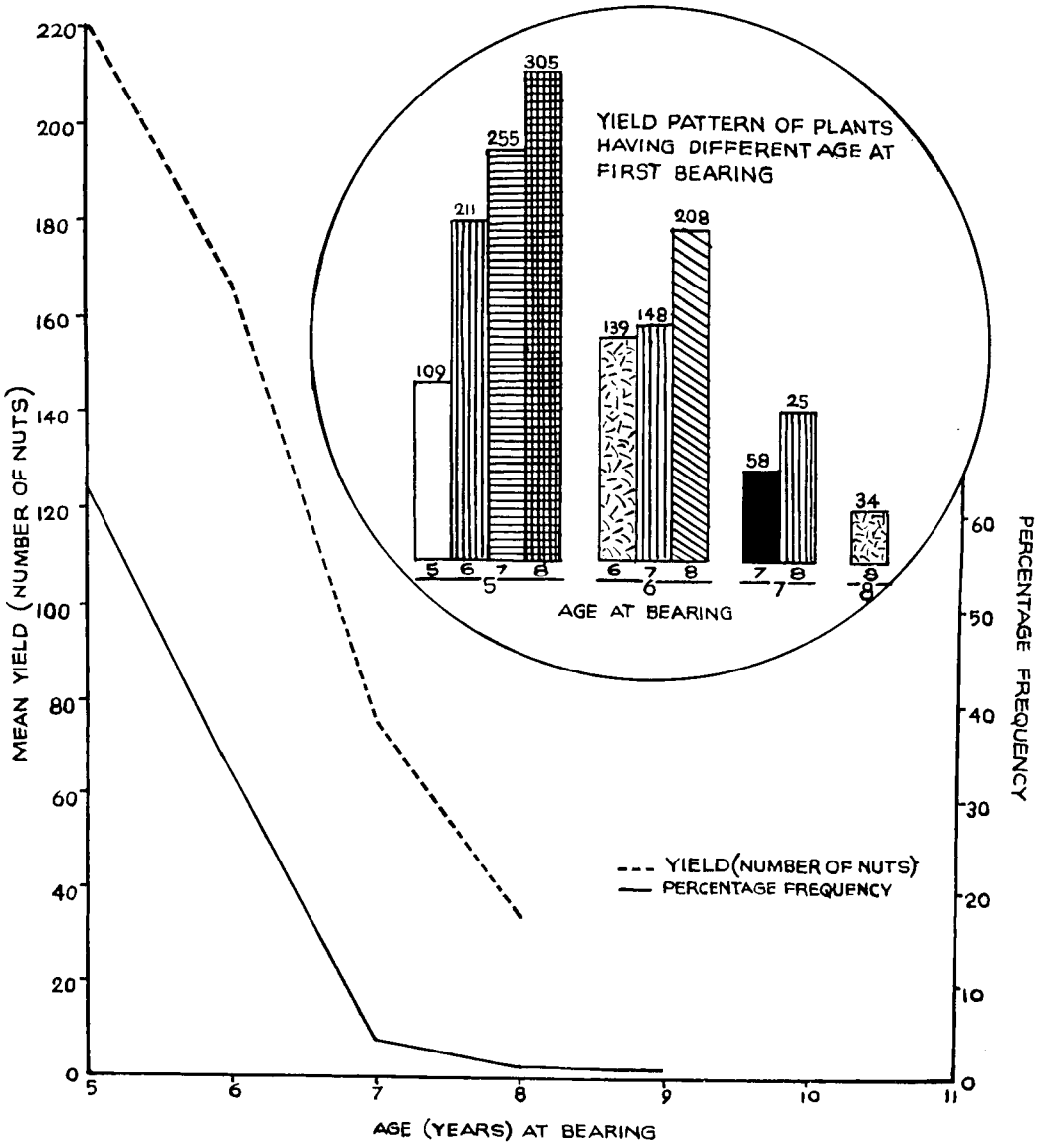


Fig. 3.55 Relationship between age at bearing and yield

A field trial was initiated at Vittal during 1963 to critically evaluate the possible beneficial effects of the existing practice of selection of seednuts from healthy and regularly high yielding palms and to fix selection standards for mother palms, seednuts, and seedlings. The treatments were unselected bulk nuts; selected bulk nuts; unselected nuts from mother palms; selected nuts from mother palms; selected nuts from non-prepotent mother palms and selected nuts from prepotent mother palms. The data on seed weight, number of days taken for germination, seedling girth, seedling height and number of leaves (at the time of transplanting) and number of nuts and weight of nuts (average over four years, 1972–'76) from two treatments *viz.*, unselected nuts and selected nuts from selected mother palms were subjected to half-sib analysis for working out genotypic and phenotypic correlations and heritabilities. Significant correlations of seed weight, seedling girth and age at first flowering with number of nuts and weight of nuts were noticed in the case of treatments with selected seednuts. It was also observed that selection of seed nuts has resulted in an improvement in heritability values for all the characters except for height and number of leaves (Table 3.17). However, heritability values for number of nuts and weight of nuts were low thereby suggesting that selection based on yield alone may not be worth practising (Bhagavan et al., 1981).

Table 3.17. *Heritability estimates for various characters*

Characters	Heritability	
	Unselected nuts	Selected nuts
Seed weight	0.14	0.33
Germination	0.53	0.65
Girth	0.08	0.25
Height	0.59	0.58
Number of leaves	0.23	0.23
Age at flowering	0.15	0.26
Number of nuts	0.06	0.25
Weight of nuts	0.08	0.29

iii. *Mass pedigree selection*

With the primary objective of the attainment of increase in yield, besides the seedlings and mother palm selection standards worked out, a modified mass pedigree selection programme was initiated in arecanut (Bavappa and Ramachander, 1967c; 1968a; 1968b). Mother palms were selected from the farmers' gardens of the Dakshina Kannada region and 41 families with 2,966 plants were raised at

Vittal. Bulk norm and individual norm tests were applied to screen the families and individuals within the selected families. Ten palms belonging to three families were selected and the seedlings raised from the individual plants thus selected, were grown in replicated progeny rows alongwith proper controls. The process of screening the families based on the bulk norm test was repeated and plants of selected families which yielded less than the garden family mean were eliminated. Thirty–eight palms belonging to six treatments and two families passed the test. However, it was found that in all these families, the observed and expected genetic gains for wet weight of nuts were very low; the expected gain for number of nuts was also found to be low; falling below the population mean. The result in effect showed that selection as practised in this experiment was ineffective in improving the yield (Anonymous, 1981).

A further refinement of the above selection programme was also suggested by Bavappa and Ramachander (1967b). They presumed that screening individual plants based on characters of high heritability and correlation with yield, prepotency, selection index, desirable characters such as resistance to pests and diseases and effecting controlled pollination between selected palms in addition to the bulk norm test and single norm test are likely to be more advantageous than simple mass pedigree selection.

3. Hybridisation

Choice of parents possessing desirable characteristics is a pre-requisite for any effective breeding programme. The CPCRI Regional Station, Vittal has a live herbarium of *Areca* species and cultivars mainly from South East Asia and South Asian countries, possessing large number of desirable characters and offer choice of selection of parents depending on the breeding objectives. Distribution of such desirable characters in different accessions of *Areca* is listed in Table 3.18.

Taking into consideration the available variability, hybridisation work in *Areca* was initiated with the following specific objectives:

1) To evolve varieties with high yield and regular bearing, 2) to combine large sized fruit with more number of nuts per bunch, 3) to combine semi-tall early bearing and high yielding characteristics of *Mangala* with quality of 'Sreevardhan', 4) to evolve varieties tolerant to yellow leaf disease, 5) to transfer the suckering habit, more number of female flowers and high percentage of set from *A. triandra* to *A. catechu* 6) to study the genetics of dwarfness, suckering habit etc. and 7) to study the combining ability for exploitation of hybrid vigour.

Table 3.18. *Distribution of characters in different accessions*

Characters	Probable donors
High yield	*A. catechu* 'Singapore' / *A. catechu Mangala*
Early bearing	*A. catechu Mangala*
Greater number of fruits/bunch	*A. catechu* 'Thirthahalli'
Better quality	*A. catechu* 'Sreevardhan'
Fruit size (large)	*A. catechu* 'South Kanara'
Regular bearing	*A. catechu* 'South Kanara'
Dwarfness	*A. catechu* Dwarf mutant
Tolerance to yellow leaf disease	*A. catechu* Dwarf mutant
More number of female flowers per bunch	*A. triandra*
High percentage of fruit set	*A. triandra*
Suckering habit	*A. triandra*

i. *Hybrid performance*

An inter-varietal crossing programme was initiated at Vittal during 1965 with *Mangala,* a semi-dwarf high yielding type as female parent and 'Sreevardhan', 'Local' and 'Thirthahalli' as male parents. Other inter-varietal hybrids available are involving 'Local' and 'Indonesia 1,' 'Indonesia 2' and 'Andamans' and hybrids derived from *Mangala* and four selected exotic types (VTL–11, VTL–12, VTL–13 and VTL–17) and two indigenous types ('Mohitnagar' and 'Thirthahalli' and Dwarf mutant).

Hybrids derived from crosses 'Local' × 'Indonesia' 1 (VTL–47), 'Local' × 'Andamans' (VTL–45), 'Local' × 'Indonesia' (VTL–48) and 'Nicobar' (VTL–46) × 'Local' showed earliness in bearing, large sized inflorescence, large number of female flowers and heavier crown habits (Anonymous, 1970). Hybrid vigour for leaf length, number of leaves, number of leaflets, length of leaflet, breadth of leaf sheath and girth at crown has also been observed for these characters (Anonymous, 1971).

Among the hybrids from *Mangala* × 'Local' and *Mangala* × 'Sreevardhan', the latter group was vigorous as observed from increased height and girth of stem and number of leaves (Anonymous, 1971).

Inter-varietal crosses were carried out at Vittal among *Mangala,* VTL 11, 13 and 17, 'Mohitnagar', 'Thirthahalli' and Dwarf mutant during 1975. The seedlings raised from these crosses were planted in a field trial at Palode, South Kerala during 1976 with a view to studying the disease reaction to the yellow leaf disease of arecanut. Observations recorded till 1981 indicated that hybrid seedlings derived from crosses involving Dwarf mutant have some degree of tolerance. (Table 3.19).

Table 3.19. *Disease reaction of hybrids derived from crosses involving Dwarf mutant*

Crosses	No. of palms available out of 48 in all the replications	No. of diseased palms	% of palms affected
Mangala × Dwarf	36	1	2.8
VTL 13 × Dwarf	39	5	12.8
Mohitnagar × Dwarf	43	0	0.0
Thirthahalli × Dwarf	35	2	5.7
Dwarf × VTL 11	17	0	0.0
Mangala	30	3	10.0
Dwarf	41	2	4.9

ii. *Interspecific hybrids*

Reciprocal crosses between *A. catechu* and *A. triandra* were made at Vittal during 1965–'66 and detailed morphological and cytological investigation on these hybrids were reported by Bavappa (1974).

The F_1 hybrids of *A. catechu* × *A. triandra* had only one stem as in *A. catechu* indicating the dominance of single stem (Fig. 3.56). As discussed elsewhere (Table 3.8) the reciprocal hybrids are soboliferous like *A. triandra* parent and based on this, as well as other supporting evidences *A. triandra* is considered to be apomictic (Bavappa, 1974; Bavappa and Nair, 1975). The *A. catechu* × *A. triandra* hybrids mostly equalled the parents in respect of internodal distance at fixed mark and leaf length and it was suggested that a dosage effect of gene for these characters are operative in *Areca.* The similarity of the hybrids to their respective female parents in respect of leaves per clump indicated that this character might be maternal in inheritance.

A. catechu × *A. triandra* hybrids exhibited hybrid vigour for number of male flowers per bunch, number of female flowers, length of spadix and girth of stem at fixed mark, the maximum hybrid vigour being for the number of female flowers (Table 3.8). However variation in hybrid vigour expression in hybrids derived from different cultivars of *A. catechu* and ecotypes of *A. triandra* was observed.

The number of stamens in *A. catechu* parent is mostly six (with some variability) while as the very name indicates *A. triandra* has three anthers. The number of stamens in *A. catechu* × *A. triandra* hybrids vary from 3 to 6 indicating probable quantitative inheritance. Since all the hybrids of *A. catechu* × *A. triandra* have paired and biseriate arrangement of male flowers on the rachilla, in contrast

Fig. 3.56 *A. catechu*×*A. triandra* hybrid

to single and alternate arrangement in *A. catechu* and in pairs and uniseriate in *A. triandra,* Bavappa (1974) concluded that biseriate is dominant over uniseriate and paired condition over singleness.

The inheritance of fruit size in *Areca* is presumed to be quantitative since the fruit size in all the *A. catechu* × *A. triandra* hybrids were intermediate (Table 3.9) (Bavappa, 1974).

The interspecific hybrids between *A. catechu* and *A. triandra* showed high sterility and also hybrid vigour for many characters. This is to be expected in an interspecific cross involving genetically divergent parents. The studies on intercluster divergence showed that the genetic distance between *A. catechu* and *A. triandra* is wide (Bavappa, 1974). Since it has been possible to backcross the F1 hybrids of *A. catechu* × *A. triandra* to *A. catechu,* the possibilities of transferring high fruit set reported in *A. triandra* (Bavappa, 1966a, 1966b) to *A. catechu* are bright. As the sterility observed in the hybrids appears to be due to disharmonious interaction between the cytoplasm of *A. catechu* and genotype of *A. triandra,* restoration of fertility through repeated backcrosses to *A. catechu* may be feasible and it may be possible to evolve better varieties combining qualities of both the species.

4. Biometrical studies

i. *Correlation and heritability*

In an attempt to establish relationship between vigour of the seedlings and subsequent yield of arecanut palm, Bavappa and Ramachander (1967b) worked out phenotypic and genotypic correlation between some of the morphological characters of the seedlings at the time of planting as well as one and two years after, with the yield in the first four years of bearing. From the phenotypic correlation it is observed that morphological characters like number of leaves, girth at collar and height at the time of planting are correlated with the yield during the first year of bearing only. Characters recorded, one and two years after planting have significant positive correlation with yield in all the four years except for the girth at last exposed node for the second year (Table 3.20).

Genotypic correlation worked out with yield during the first four years of bearing showed that the number of leaves at the time of planting, girth at collar, one year after planting and number of nodes two years after planting have significant positive correlation with yield during all the four years (Table 3.20).

Table 3.20. *Phenotypic and genotypic correlations between morphological characters of seedlings and their yield*

Morphological characters	Phenotypic correlation with yield during				Genotypic correlation with yield during				Heritability
	First year	Second year	Third year	Fourth year	First year	Second year	Third year	Fourth year	
I year (at the time of planting)									
Number of leaves	0.21**	0.04	0.04	0.04	0.32*	0.12	0.21	0.39**	0.92
Girth at collar	0.12*	0.04	0.03	0.05	0.12	-0.35*	-0.40**	-0.16	0.96
Height	0.19*	0.06	0.06	0.06	0.36*	-0.18	-0.18	-0.15	0.80
II Year (one year after planting)									
Number of leaves	0.26**	0.17*	0.12*	0.09*	0.98**	-0.32*	-0.08	-0.01	0.32
Girth at collar	0.21**	0.27**	0.16*	0.23**	0.46**	0.10	0.16	0.28*	0.80
Height	0.22**	0.27**	0.22*	0.19**	0.31*	-0.25	-0.41**	-0.27	0.32
III Year (two years after planting)									
Number of leaves	0.24**	0.13*	0.15*	0.26*	0.19	-0.08	-0.09	0.14	0.32
Girth at permanent mark	0.16*	0.17*	0.14*	0.16*	0.34*	-0.15	0.68**	0.45**	0.36
Girth at last exposed node	0.19*	0.09	0.23**	0.13**	0.33*	-0.03	0.21	0.25	0.64
Number of nodes	0.20**	0.26**	0.13*	0.17*	0.39**	0.28*	0.03	0.12	0.96

* Above P 0.05 level of significance : 0.10
** Above P 0.01 level of significance : 0.20

* Above P 0.05 level of significance : 0.28
** Above P 0.01 level of significance : 0.38

Bavappa and Ramachander (1967c) observed that heritability for yield in arecanut is very low (0.20) and hence practically no improvement in yield could be achieved by direct selection for this character. To achieve improvement in yield by selection, they tried to identify characters having high heritability as well as correlation with yield. Values in respect of phenotypic, genotypic and environmental correlations of these characters with yield and heritability are given in Table 3.21.

Table 3.21. *Correlation of different characters with yield (number of nuts) and their heritability*

Characters	Correlations			h^2
	Phenotypic	Genotypic	Environmental	
Age at first bearing	-0.45	-0.55	-0.65	0.72
Number of leaves shed	0.19	0.53	0.35	0.32
Number of inflorescences produced	0.41	0.02	0.59	0.46
Number of bunches harvested	0.72	0.27	0.77	0.10
Number of female flowers produced	0.55	-0.44	0.65	0.08
Number of nuts set	0.97	1.08	0.97	0.03
Percentage of nut set	0.78	0.88	0.75	0.33
Mean weight	-0.28	-0.58	-0.24	0.07
Number of nuts per bunch	0.84	0.86	0.82	0.22
Percentage of bunches to inflorescences	0.60	0.42	0.63	0.16
Percentage of inflorescence to leaves shed	0.42	0.04	0.69	0.60

Among the 11 characters considered, age at first bearing alone has high heritability and correlation with yield. The percentage of inflorescence to leaves shed and number of inflorescences produced also have high heritability. But in view of low genotypic correlation of these characters with yield, selection based on these two characters would not help in improvement of yield. Percentage of nut set is highly correlated with yield, but the heritability is relatively low. Eventhough the mean weight of nut is negatively correlated with yield, in the absence of a threshold value, the total weight of nuts produced increased with the number of nuts and this negative correlation did not set a limit to the possible yield improvement (Bavappa and Ramachander, 1967c; Anonymous, 1969b).

ii) *Selection index*

Due to the limited variability in age at first bearing, selection based on this character (which has got high heritability and highly significant correlation with yield) may not lead to a very significant improvement in yield. Under such

a situation, Ramachander and Bavappa (1972) attempted to refine the selection method adopting selection index technique. They pointed out that standardisation of such selection procedures is particularly useful in perennial crops where once the genetically potential parents are identified, planting material could be continuously collected for a number of years. They standardised the selection technique by working out selection indices and set up the selection differential to select the palms which passed the limit. For this study, 17 growth measurements taken at various stages of growth, 12 yield components as well as cumulative yield for first four years in respect of 220 palms belonging to 10 families of 'Vittal' type of arecanut were used. From the different indices and genetic advance (G.A.) presented (Table 3.22) it was observed that the selection index based on 17 growth measurements gave an efficiency of 476% over straight selection, while all the 29 characters gave an efficiency of 498%. However, it was pointed out that from the point of view of practical breeding, inspite of slightly higher efficiency from selection utilising all the 29 characters, an index based on growth measurements would be preferred because of the ease of calculation as well as possibility of raising seed gardens with such selected seed donors. From the selection index presented by them, it was observed that as against, an expected genetic advance of 57.11 due to straight selection, a simpler index using two characters at the time of transplanting *viz.*, the number of leaves and height gives a genetic advance of 190% and relative improvement of 332%. A simplified formula utilising these two characters for selection of seedlings has been suggested by Bavappa (1970) as explained earlier.

iii. *Genetic divergence*

Bavappa (1974) recorded morphological, anatomical and yield characters for 13 cultivars of *A. catechu* and four ecotypes of *A. triandra* for the years 1963, 1966 and 1972. The analysis of variance of the results obtained in 1963 showed that the differences between cultivars are highly significant for all the six morphological characters (Table 3.23). A combined analysis of the data for two years for 24 common characters recorded during 1967 and 1972 also revealed significant difference between cultivars for all characters (Table 3.24). A significant interaction between years and cultivars was seen in the case of height, girth, internodal distance, number of bunches and inflorescences on the palm, length and breadth of leaf sheath, length and volume of nut and length, breadth, weight and volume of kernel.

Bavappa (1974) also worked out 136 D^2 values between cultivars, the number of characters being unequal in different years. The magnitude of D^2 values

Table 3.22. *Constants of different characters for calculating selection indices, genetic advance (GA) and relative improvement (RI)*

Characters		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
					GROWTH MEASUREMENTS				
At the time of planting									
X_1	Number of leaves	180.623	187.865		193.133	206.618			
X_2	Girth at collar (cm)	46.043	50.933		114.644				
X_3	Height (cm)	-6.299	-6.302		-6.551	-4.966			
After one year growth in the field									
X_4	Number of leaves	2.041	3.517				3.233		
X_5	Girth at collar (cm)	12.407	13.640				18.245		
X^6	Height (cm)	-2.367	-2.285				-0.621		
X_7	Number of nodes	-60.421	-68.296				-75.460		
After two years growth in the field									
X_8	Number of leaves	-49.358	-54.352					-47.532	
X_9	Girth at permanent mark (cm)	12.126	11.435					11.480	
X_{10}	Girth at last exposed node (cm)	-13.341	-12.089					-14.859	
X_{11}	Number of nodes	49.347	61.061					20.804	
After six years of growth in the main field									
X_{12}	Number of leaves	-19.161	-33.384						9.066
X_{13}	Girth at collar (cm)	0.871	2.757						3.388
X_{14}	Girth at permanent mark (cm)	-13.245	-15.140						-9.532
X_{15}	Girth at last exposed node (cm)	-8.203	-3.564						-7.622
X_{16}	Total height (cm)	1.152	0.909						0.744
X_{17}	Number of nodes	-5.121	-12.667						-4.415
					YIELD COMPONENTS				
X_{18}	Number of leaves shed	-60.308		-32.811					
X_{19}	Number of inflorescence produced	84.710		23.316					
X_{20}	Number of bunches harvested	-67.710		-107.216					
X_{21}	Total number of female flowers	-0.238		-0.031					
X_{22}	Total number of fruits	0.678		1.036					
X_{23}	Percentage of fruit set	-5.378		2.128					
X_{24}	Mean weight per nut (gm)	-1.878		1.202					
X_{25}	Mean number of nuts/bunch	0.509		-3.401					
X_{26}	Percentage of bunches harvested	1.529		0.881					
X_{27}	Inflorescence to leaves (%)	-3.706		-1.997					
X_{28}	Nuts harvested to set (%)	0.968		6.339					
X_{29}	Kernel to wet weight (%)	-0.632		-1.427					
	GA	284.694K	271.854K	116.274K	200.884K	190.020K	96.050K	126.705K	80.450K
	R.I(%)	498.484	476.011	203.589	351.749	332.726	168.180	221.863	140.860

GA due to straight selection=57.110 K, where K is a constant

Table 3.23. *ANOVA of means for six characters in arecanut (1963)*

Characters	Replications (3 d.f.)	Cultivars (16 d.f.)	Error (48 d.f.)
		Mean sum of squares	
Total number of suckers	1.02	8.51**	1.14
Height	531.33	5165.12**	422.83
Girth at collar	38.43	879.78**	53.13
Girth below crown	4.23	322.06**	11.65
Number of leaves	0.33	7.22**	0.85
Number of nodes	1.06	54.82**	3.98

**Significant at P = 0.01

indicated that considerable divergence exists between many of the cultivars in all the years. He grouped 13 cultivars and four ecotypes from nine countries into six clusters for the independent years 1963, 1966 and 1972 and found that though the number of clusters were the same, constituents in the different clusters were slightly different in different years (Table 3.25). The number of clusters and pattern of clustering were more or less similar for the years 1966 and 1972. In the pooled analysis, the number of clusters got reduced from six to five. However, the pattern of clustering was more or less in conformity with the groups obtained for the individual years. The spatial diagram showing the distribution of clusters in 1966 and 1972 (pooled) is given in Fig. 3.57.

All the four ecotypes of *A. triandra* were in one cluster in the pooled analysis and this cluster continued to show maximum divergence from the rest. The divergence between clusters IV and V were due to the differences in nut and kernel characters, breadth of leaf sheath, breadth of leaflets and number of leaflets. Bavappa (1974) based on the analysis concluded that detection of the genetic divergence in the early years of productive phase is of considerable advantage in formulating breeding programme in a perennial crop like arecanut.

The rankings obtained by the different characters during 1966 for their contribution towards overall genetic divergence showed that the mean volume of nut and breadth of kernel were the characters of primary importance. For divergence between *A. triandra* and *A. catechu*, mean length of fruit was found to be second in importance, next only to volume of nut. The results of characters for 1972 and the pooled data also revealed the importance of nut and kernel characters in differentiation within *A. catechu* cultivars and between *A. catechu* and *A. triandra* types. The results obtained from canonical analysis were also in broad agreement

Table 3.24. *Pooled ANOVA of means for 24 characters over two years (1966 and 1972) in arecanut*

Characters	Years (1 d. f.)	Replication (3 d. f.)	Years × replication (3 d. f.)	Cultivars (16 d. f.)	Years × cultivars (16 d. f.)	Error (96 d. f.)
	Mean sum of squares					
Height above fixed mark (cm)	598.004**	272.00**	147.00[2]	140.46[3]**	305.62[2]**	5658.33
Girth at fixed mark (cm)	59.00	37.33	5.00	985.13**	16.31	21.00
Girth below crown (cm)	720.00**	26.67	20.67	623.75**	11.38	19.15
Internodal distance at fixed mark (cm)	34.00**	17.43**	5.20	43.06**	6.81*	3.46
Internodal distance at last node (cm)	670.60**	7.23	12.53	57.27**	18.11*	8.60
Number of bunches per palm	154.60**	11.91**	0.44	16.99**	18.99**	4.48
Number of inflorescence on the palm	855.01**	9.81	5.11	106.97**	144.41**	11.99
Total number of leaves on the palm	0.90	1.53	0.43	6.13**	1.09	0.68
Angle of leaf to the stem (°)	1266.96**	67.05	184.21*	537.08**	315.57**	75.86
Number of leaflets	28.00	29.00	9.67	643.56**	15.38	23.06
Number of midribs	27.00	32.33	55.33	701.63**	35.23	39.83
Length of longest leaflet (cm)	1.30	123.33	656.67	1003.75	772.50	745.10
Breadth of broadest leaflet (cm)	1.20	4.40	0.83	34.29**	1.54	3.34
Length of leaf without sheath (cm)	282.70[2]**	173.33	360.00	5098.12**	1508.12**	412.71
Length of leaf sheath (cm)	472.00*	26.62	92.67	1358.00**	75.56	98.95
Breadth of leaf sheath (cm)	6196.00**	12.67	158.00*	556.69**	90.56*	44.55
Mean fruit length (cm)	1.49**	0.18	0.13	10.20**	0.17	0.15
Mean fruit breadth (cm)	0.23	0.11	0.11	10.24**	0.14	0.09
Mean weight of nut (gm)	64.00	58.67	101.33	2178.56**	69.94	50.51
Mean volume of nut (cc)	624.00**	93.33	38.00	3213.12**	68.75	47.54
Mean kernel length (cm)	0.39*	0.08	0.02	1.10**	0.11	0.08
Mean kernel breadth (cm)	0.41*	0.12	0.06	4.96**	0.12	0.09
Mean weight of kernel (gm)	47.20*	18.07	1.23	240.24**	24.13**	6.91
Mean volume of kernel (cc)	172.40**	16.80	1.67	221.65**	33.78**	6.74

* Significant at P = 0.05
** Significant at P = 0.01

Superscript 2 3 and 4 indicate that the figure should be multiplied by 10^2, 10^3 and 10^4 respectively

Table 3.25. *Composition of clusters in different years*

Cluster number	1963 (6 characters)	1966 (40 characters)	1966 (24 characters)	1972 (24 characters)	1966 and 1972 pooled (24 characters)
I	2,3,4,9	3,6,7,8,9,12	7,8,9	7,8,9,12	7,8,9
II	13,14,15	14,15	13,14,15,16	13,14,16	13,14,15,16
III	1,5,6,7	4,5,11,17	4,5,6,11	1,3,4,5,6,11,17	1,3,4,5,6,11,17
IV	10,11,12,17	1,10	1,3,10,12	10	10,12
V	8	2	2	2	2
VI	16	16	17	15	–
VII	–	13	–	–	–

1. Ceylon–1
2. Ceylon–2
3. Indonesia–6
4. Saigon–1
5. Saigon–2
6. Saigon–3
7. Br. Sol. Islands–1
8. Br. Sol. Islands–2
9. Br. Sol. Islands–3
10. China
11. Singapore
12. Fiji
13. Indonesia–1
14. Indonesia–2
15. Mauritius
16. Ceylon–3
17. South Kanara

Note: Numbers 1–12 and 17 – *A. catechu*
Numbers 13–16 – *A. triandra*

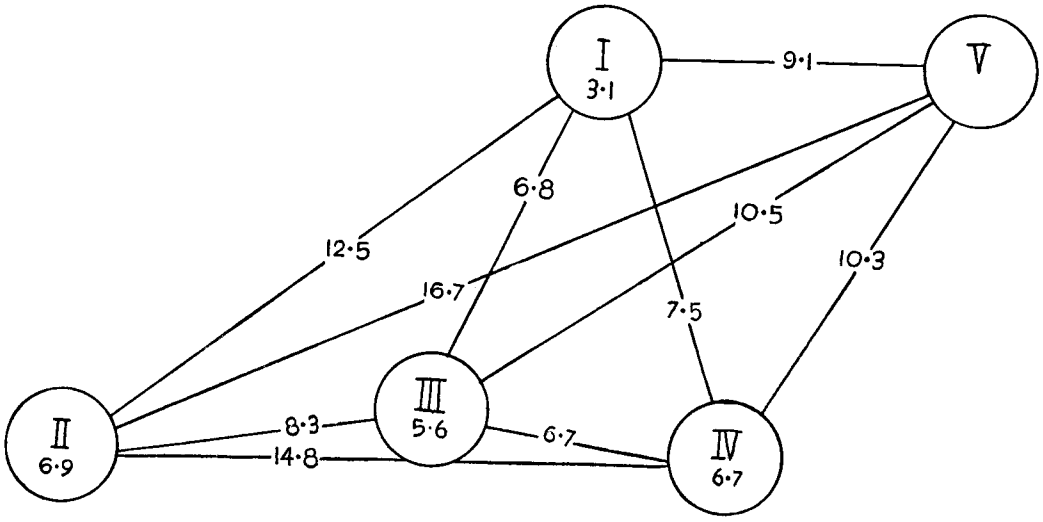


Fig. 3.57 Spatial diagram showing the distribution of clusters (1966 and 1972 pooled)

with the clustering pattern found from D^2 analysis. However, Bavappa (1974) concluded that the canonical analysis could be of only limited utility in view of the fact that the first two canonical roots accounted for only 85% of the variation or less.

The grouping obtained by D^2 analysis revealed that the three cultivars each from Saigon and British Solomon Islands and the two ecotypes of *A. triandra* from Indonesia were invariably in one cluster each. As against this, close

similarity between the cultivars from different countries has also been observed. The cultivar from Singapore got grouped with the three cultivars from Saigon in one cluster. A similar affinity between the two geographically distant cultivars was shown by 'Ceylon–1' and 'Indonesia–6,' both always coming within the same cluster. The local cultivar has been found to be invariably associated with the cultivar from Singapore in forming the cluster. Of the two cultivars of *A. catechu* from Ceylon, 'Ceylon–2' was always forming a separate cluster indicating its distinct nature of divergence. The clustering pattern of cultivars and ecotypes revealed that geographic diversity need not always be related to genetic diversity (Bavappa, 1974).

III. Evolutionary significance

Based on the clustering pattern of certain cultivars of *A. catechu* from countries such as India, Sri Lanka, Singapore, Indonesia and Saigon, Bavappa (1974) deduced that probably both *A. catechu* and *A. triandra* had their origin in group of islands in Indonesia as concluded earlier (Bavappa 1963; Corner, 1966). He presumed that probably these species moved to west through Malaysia to India, Sri Lanka and as far west as Mauritius, all-through maintaining their specific identity, while *A. catechu* found its way to north (Saigon) as well.

Bavappa (1974) also deduced the evolutionary course of *A. catechu*, *A. triandra* and *A. concinna* on the evidences of their distribution, similarities of synthetic hybrid between *A. catechu* and *A. triandra* to *A. concinna* and also the natural occurrence of *A. catechu* × *A. triandra* hybrids. Based on the available information, he concluded that probably *A. catechu* and *A. triandra* were the putative parents of *A. concinna*.

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4

CROP MANAGEMENT

A. SOILS AND MANURES

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I. Soils

In India arecanut is mostly grown in high rainfall regions of Kerala, Karnataka, Assam, West Bengal, Tamil Nadu and Maharashtra. Andamans is also considered as an ideal area for arecanut cultivation (Nambiar, 1954). The largest area under the crop is found in gravelly laterite soils of red clay type of southern Kerala and coastal Karnataka (Nambiar, 1949). In the plain region or the *Maidan* part of Karnataka, arecanut is planted in fertile clay loam soils (Naidu, 1962). These soils may have at places a large admixture of tank silt particularly in places where tank irrigation is practised. Of all the soils, the deep black fertile clay loams in the tank irrigated areas supported luxuriant tree growth. Sticky clay, sandy, alluvial, brackish and calcareous soils are not favourable for arecanut cultivation (Aiyer, 1966). In Malaysia and Fiji, arecanut is cultivated in the hot, moist, rich alluvial areas of the coastal belt (Nambiar, 1949).

1. Fertility status of soils

Though a comprehensive survey of fertility constituents of soils of arecanut growing areas has not been carried out, some information on the native fertility status of soils has been gathered from the Arecanut Research Stations situated in various states of the country (Anonymous, 1973; Mohapatra, 1977). In general, the organic carbon content of the soil is high. Available P in the soils of Peechi (Kerala), Mohitnagar (West Bengal) and Kahikuchi (Assam) is medium, whereas it is low in the soils of Vittal, Hirehalli (Karnataka) and Palode (Kerala). Soils from all the stations except that at Mohitnagar are found to be medium to high in available K status. The pH of the soils is acidic to neutral in all the stations except that at Hirehalli, where it is neutral to alkaline. The total CaO and MgO contents of soils from Vittal and Palode are lower than those of others. The Al_2O_3 content is more

than that of Fe_2O_3 in all the soils (Table 4A.1). Texturally the soils of Hirehalli are clay loam and that of Vittal are sandy clay loam, while those from Peechi, Palode, Mohitnagar and Kahikuchi are sandy loam (Mohapatra, 1977).

Iyengar (1954) reported that the total N content of the soils varied from 0.03–0.22% in some of the arecanut gardens in Karnataka.

Khadilkar, Badhe and Pandya (1964) described soil profiles from arecanut growing areas of Kolaba and Ratnagiri districts of Maharashtra. The major soils are lateritic, mildly acidic, rich in total N and micronutrients and low in bases, P and K. The alluvial soils from the coastal region are found to be neutral, base saturated and rich in organic matter.

II. Manures

1. Phosphorus and its mobility

The movement of PO_4 ion in the soil profile when applied at the rate of 50, 100 and 200 kg of P_2O_5 per ha as superphosphate was studied in a field experiment at Vittal and the results showed that after 24 hr of application of superphosphate, available P_2O_5 in surface soil (0-5 cm depth) increased by 23, 31 and 38 folds over initial level with increase in dosage of application. It decreased with increase in depth and time of sampling. The increase in available P_2O_5 and movement of PO_4 ion in the profile were found to be associated with the level of application. It was also observed that the difference between available P_2O_5 at the initial stage and 120 days after application was negligible (Table 4A.2) (Anonymous, 1970).

Another field experiment was conducted with different sources of phosphorus *viz.*, superphosphate, (0:16:0), Suphala (20:20:0), Factamfos (20:20:0) and Thermophosphate (0:17.5:0) at 40 kg and 60 kg P_2O_5 and Ultraphos (0:33:0) at 80 kg and 120 kg P_2O_5 per 500 palms for three years to assess the release of P from these fertilisers in soil. Soil and leaf sample were collected in March, June and September and analysed for their P content (Table 4A.3) (Anonymous, 1974). Thermophosphate and Suphala applied at 60 kg P_2O_5 per 500 palms were superior with respect to soil available P_2O_5. Except for Ultraphos, all the carriers at 60 kg P_2O_5 per 500 palms gave significantly more soil available P_2O_5 than the 40 kg P_2O_5 dose. There was also a significant reduction of available phosphorus (Bray-I) in soil from March to September. When adjudged by the standard of 25 ppm of P_2O_5 as the level of sufficiency in soil, all the five phosphatic fertilisers applied at their higher

Table 4A.1. *Nutrient status of soils (0–25 cm depth) of experimental stations under arecanut*

Stations	pH	Organic carbon (%)	Total N (%)	Available		CaO (%)	MgO (%)	Fe_2O_3 (%)	Al_2O_3 (%)
				P_2O_5 (ppm)	K_2O (ppm)				
Vittal (Karnataka)	5.3–5.6	0.7–1.1	0.05–0.09	3.8–7.1	34–85	0.07–0.30	0.6–1.7	8.8–12.0	12.0–21.4
Hirehalli (Karnataka)	6.5–8.2	0.3–1.4	0.04–0.19	Trace–5.5	30–108	0.30–0.38	0.6–1.1	7.2–19.2	11.3–39.0
Peechi (Kerala)	5.1–5.6	1.0–2.0	0.06–0.16	50–81.0	115–130	0.53	1.7–2.3	8.0–11.2	17.1–24.6
Palode (Kerala)	4.9–5.0	0.7–1.4	0.06–0.13	Trace–3.0	81–91	0.15–0.23	0.6–1.1	4.8–7.2	18.0–30.9
Mohitnagar (West Bengal)	5.7–6.2	0.1–2.2	0.14–0.22	9.2–69.1	8–65	0.23–0.30	1.7–2.9	4.0–7.2	4.8–14.5
Kahikuchi (Assam)	5.1–5.3	0.5–1.8	0.03–0.12	9.6–29.0	70–190	0.15–0.30	1.1–2.3	2.4–8.0	6.5–13.6

Table 4A.2. *Available P_2O_5 (ppm) in soil profile*

Sampling intervals in days	0 kg P_2O_5/ha					50 kg P_2O_5/ha					100 kg P_2O_5/ha					200 kg P_2O_5/ha				
	Depth of soil sampling in cm					Depth of soil sampling in cm					Depth of soil sampling in cm					Depth of soil sampling in cm				
	0–5	5–10	10–15	15–20	20–30	0–5	5–10	10–15	15–20	20–30	0–5	5–10	10–15	15–20	20–30	0–5	5–10	10–15	15–20	20–30
Initial	5.2	5.7	4.8	3.4	2.8	5.0	5.9	4.5	2.4	2.7	4.9	4.9	3.9	2.2	2.6	5.5	5.5	4.5	3.3	2.9
1	5.2	5.2	3.8	2.4	2.8	111.4	25.6	11.1	5.5	4.0	154.1	78.7	33.3	12.0	4.9	240.3	127.8	37.0	22.0	9.4
15	5.7	6.6	4.3	2.5	2.7	34.0	16.4	5.6	3.8	3.4	71.6	33.7	11.0	8.7	3.7	117.9	54.4	27.0	16.4	9.1
30	6.2	6.9	5.6	3.5	3.2	22.5	9.5	5.2	3.1	3.0	40.9	16.5	9.4	7.4	3.9	88.6	28.5	17.0	12.4	7.1
60	6.0	6.2	3.9	2.8	2.2	12.6	5.2	3.8	2.0	2.4	18.0	11.0	6.0	3.9	3.2	52.1	17.8	10.7	7.3	3.0
120	6.0	6.2	4.0	2.0	2.2	10.8	5.0	3.8	2.3	2.3	12.5	8.0	4.0	3.9	3.0	22.9	10.2	8.7	5.3	3.4
180	5.8	5.5	4.0	2.1	2.2	7.5	5.5	4.0	2.4	2.7	9.2	6.2	3.9	4.1	2.9	12.6	9.2	5.0	4.3	3.1

dose were equally good from the point of view of meeting P requirement of arecanut. The results also showed that there was no difference in yield due to the sources tried. Eventhough differences in soil available P was observed, leaf P levels did not show any difference due to treatments (Anonymous, 1974).

Table 4A.3. *Release of available phosphorus from different phosphatic carriers in soil (mean values of P_2O_5 in ppm)*

Treatments (kg P_2O_5/500 palms)	Months			Mean
	March	June	September	
Superphosphate 40 kg	35.20	19.95	15.30	23.50
Superphosphate 60 kg	79.86	59.09	26.20	55.10
Factamfos 40 kg	27.60	17.07	11.00	18.60
Factamfos 60 kg	76.66	43.19	17.20	45.70
Suphala 40 kg	36.93	50.98	14.83	34.30
Suphala 60 kg	101.86	110.88	26.60	79.80
Thermophosphate 40 kg	69.60	63.69	24.71	52.70
Thermophosphate 60 kg	120.00	107.65	36.53	88.10
Ultrafos 80 kg	25.00	12.91	9.60	15.60
Ultrafos 120 kg	29.20	32.65	15.26	25.70
Mean	60.20	51.80	19.70	

LSD (for months at 1% level) = 6.50 LSD (for fertilisers at 1% level) = 19.90

2. Green manuring

Green leaf manuring is an accepted practice in arecanut garden (John, 1952; Bhat, 1955). *Crotalaria anagyroides* and *C. striata* are recommended as good green manure crops in the areca gardens of *Malnad* areas of Karnataka (Krishnappa, 1962). Incorporation of *Stylosanthes gracilis* increased organic carbon and nitrogen contents of soil (Anonymous, 1969).

Trials at Vittal, Hirehalli and Mohitnagar showed that *Pueraria javanica* and *Mimosa invisa* are good green manures and cover crops in arecanut gardens from point of view of their green matter yield and nutrient addition capacity (Table 4A.4) (Anonymous, 1974).

3. Organic matter and nitrogen

The rate of release of nitrogen from different organic manures commonly applied to arecanut *viz., Glyricidia, Mimosa,* forest leaf, compost, cattle manure and fish manure at 100 kg N per ha was estimated from an experiment at Vittal. The mineralisation of these substances was found to be complete in four months (Table 4A.5) and thereafter, the rate was very slow. It is evident that easily

Table 4A.4. *Yield of green matter, nutrient content and amount of nutrients added by different green manure crops*

Name of the crop	Mean yield of green matter 1970–'72 (tonnes/ha)	Moisture (%)	Nutrient composition (%)			Nutrient addition (kg/ha)		
			N	P	K	N	P_2O_5	K_2O
Calopogonium muconoides	7.14	78.37	2.63	0.23	2.80	40.50	7.92	51.91
Pueraria javanica	14.35	79.01	3.30	0.24	1.63	99.33	16.54	59.06
Stylosanthes gracilis	12.81	79.40	2.42	0.23	1.63	63.64	13.54	51.61
Mimosa invisa	12.62	77.63	3.96	0.34	2.00	111.67	21.62	67.90
Sesbania speciosa	5.18	77.50	2.70	0.17	1.12	31.32	4.51	15.64
Centrocema pubescens	6.90	75.20	2.54	0.24	1.75	43.43	9.21	36.02
Crotalaria anagyroides	3.39	78.30	2.81	0.27	2.12	20.51	4.51	18.62

Table 4A.5. *Ammoniacal nitrogen in soil samples incorporated with different organic manures*

Sampling intervals (months)	Ammoniacal nitrogen (ppm)						Mean
	Glyricidia	*Mimosa*	Forest leaf	Cattle manure	Compost	Fish manure	
1	4.35	1.87	1.11	0.72	0.82	10.91	3.30
2	2.18	1.30	0.97	0.53	0.66	2.20	1.17
3	0.50	1.34	0.06	0.37	0.03	2.04	0.72
4	0.22	0.50	Trace	Trace	0.17	0.32	0.26
5	0.33	0.34	0.22	0.17	0.19	0.15	0.23
6	0.18	0.30	0.32	0.20	0.20	0.13	0.22
Mean	1.29	0.94	0.45	0.33	0.35	2.62	

C. D. (P=0.05) Treatment = 0.42 C. D. (P=0.05) Month = 0.29

decomposible material gets oxidised in the course of about four months. The fish manure contributed more to the NH_4–N content and also increased soil acidity. Lime reduced the contents of NH_4–N and available K. Forest leaf and cattle manure increased organic matter content of soil (Table 4A.6) (Anonymous, 1972). The study indicated that skipping of annual application of organic manure (as practised by some farmers) in arecanut gardens is not a desirable practice.

4. Organic manures and inorganic fertilisers in arecanut cultivation

An experiment to study the long term effect of supplying nutrients as organic, inorganic, a combination of both and with and without intercultivation, on the composition of arecanut growing soils and areca palm was carried out at Vittal from 1969 to 1981. The nutrients applied were 100g N, 40g P_2O_5 and 140g K_2O per palm per year in the form of organics and inorganics.

Table 4A.6. *Organic carbon in soil samples incorporated with different organic manures at different periods after incorporation*

Sampling interval (months)	Organic carbon (%)						Mean
	Glyricidia	*Mimosa*	Forest leaf	Cattle manure	Compost	Fish manure	
1	0.21	0.26	0.31	0.34	0.29	0.28	0.28
2	0.24	0.27	0.32	0.32	0.32	0.25	0.29
3	0.21	0.24	0.36	0.29	0.30	0.26	0.29
4	0.38	0.35	0.40	0.34	0.42	0.29	0.36
5	0.25	0.25	0.35	0.27	0.24	0.24	0.27
6	0.29	0.32	0.38	0.40	0.31	0.33	0.34
Mean	0.26	0.28	0.35	0.33	0.31	0.29	

C. D. (P = 0.05) Treatment = 0.042 C. D. (P = 0.05) Month = 0.022

Application of organic manures significantly increased organic matter in soil to a higher degree than inorganic fertilisers. The plant nutrients in the soil was found to build up as a result of fertiliser application. Both organic manures and inorganic fertilisers were equally effective in building up soil available plant nutrients (Table 4A.7). Eventhough there was increase in organic carbon, available P_2O_5, K_2O and exchangeable calcium due to different treatments, in the absence of significant yield differences and also the soil nutrient levels being much higher than what is normally required for the crop, it is safe to assume that application of nutrients in the form of organic or inorganic sources, meets the needs of the crop (Anonymous, 1981).

Table 4A.7. *Changes in soil fertility parameters as a result of treatments (pre-treatment samples compared with post-treatment samples, 0–50 cm depth)*

Treatments	Soil constituents									
	pH		Organic carbon (%)		Available P_2O_5 (ppm)		Available K_2O (ppm)		Exchangeable Ca (ppm)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Organic manures	6.08	6.75	0.62	1.29	3.0	37.0	105	144	390	1115
Inorganic fertilisers	6.08	5.49	0.61	0.81	5.0	65.0	121	134	388	406
Organic manures + inorganic fertilisers	5.95	6.73	0.67	1.28	7.0	78.0	144	154	365	1166
Organic manures + inorganic fertilisers + cultivation	6.03	6.45	0.68	0.90	6.5	44.0	132	131	350	700
Organic manures + cultivation	6.13	7.25	0.64	1.60	4.8	96.0	115	235	353	1306
Inorganic fertilisers + cultivation	6.13	5.49	0.57	0.80	5.5	37.5	106	140	315	368

The rhizosphere of palms in treatments receiving organic manures had also higher microbial population (Table 4A.8) (Bopaiah and Bhat, 1981).

Table 4A.8. *Microbial population in rhizosphere of areca palms (0–30 cm)*

Treatments	Soil pH	Soil organic carbon (%)	Bacteria 10^4	Fungi 10^3	Actino-mycetes 10^3
Organic manures	7.38	2.23	129.0	29.0	10.5
Inorganic fertilisers	5.78	1.62	18.0	22.0	5.0
Organic manures + inorganic fertilisers	6.87	2.41	47.0	18.5	11.5
Organic manures + inorganic fertilisers + cultivation	6.85	1.85	136.0	22.5	34.5
Organic manures + cultivation	7.43	1.82	130.0	19.0	22.5
Inorganic fertilisers + cultivation	5.52	1.09	51.0	17.5	9.0

The soils of arecanut gardens are slightly acidic and low in general fertility. Fertilisers which increase acidity in soil could be avoided, wherever organic manures are abundantly available. Acidity adversely affects physical, chemical and biological properties of soil. Liberal application of organic matter buffers soil reaction. Lime could be added to soils, whose pH is below 5.0 to correct acidity.

The micronutrients do not have a pronounced effect on the growth and yield of arecanut (Mohapatra, 1977).

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B. AGRONOMY

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In India the use of arecanut and its cultivation constitute a distinct agricultural practice scarcely less important than that of other economic crops (Watt, 1908). In spite of this, arecanut did not receive adequate attention in the fields of research and development till about late fourties. The erstwhile Mysore Government was the first to start an Arecanut Research Station at Marthur, to study and solve the problems connected with arecanut (Nambiar, 1949). Since then substantial information on the management of the crop has been generated from a number of research stations established from early fifties.

Since arecanut is cultivated in a variety of soil and climatic conditions, it is difficult to formulate uniform agronomical practice suitable for all the situations alike.

I. Climate

1. Altitude

The altitude at which arecanut palm grows depends to some extent on the latitude. In the North-Eastern Region of India (Assam and West Bengal) where sizeable area is under arecanut, it is mostly grown on the plains, since at higher elevation the winter temperature would be too extreme for the crop. Nambiar (1949), reported that though the palm grows at altitudes up to 1000 m above sea level, at higher levels, the quality of the fruit is not good. In Wynad (Kerala) and Coorg (Karnataka) which are places of high altitude, the endosperm (kernel) of the fruit does not develop sufficient hardness, probably due to the low temperature during the developing period of fruits. Pillai and Murthy (1973) reported that altitude affects the germination of seed arecanuts as well as quality of *chali*

(dry kernel). At altitudes above 850 m, the percentage of germination of nut and the proportion of dry weight of kernel to whole fruits are less than in the lower altitudes.

2. Temperature

Arecanut grows in India within a wide range of temperature, ranging from a minimum of 4°C (as in places like Mohitnagar, West Bengal) to a maximum of about 40°C (Vittal in Karnataka and Kannara in Kerala), though the palm flourishes well within a temperature range of 14°C – 36°C. Extremes of temperature and wide diurnal variations are not conducive for the healthy growth of the palms (Nambiar, 1949). Smith (1958) reported heavy damage to the foliage and even death of arecanut palm in Florida during December 1957, when the minimum temperature was below —2.8°C. Even temperature around 5°C, with low humidity cause severe foliage damage of the palm, as observed in the Dakshina Kannada district during early seventies.

3. Rainfall

Arecanut flourishes in tracts of very heavy rainfall such as the *Malnad* of Karnataka where the annual rainfall may go up to or even more than 4,500 mm as well as in low rainfall areas like the *Maidan* parts of Karnataka or parts of Coimbatore district in Tamil Nadu where the annual rainfall is about 750 mm. In areas where there is prolonged dry spell, the palms are irrigated.

II. Nursery technique

Arecanut is an exclusively seed propagated crop. Being a perennial, it is essential that adequate care is bestowed in the selection of proper planting material. There are four important stages in the selection and raising of arecanut seedlings, *viz.*, selection of mother palms, selection of seed nuts, selection of proper techniques in germinating and raising seedlings and selection of seedlings.

1. Selection of mother palms

Age of mother palms is an important factor considered by the farmers for selecting seed nuts. Nambiar (1949) reported that while in the northern parts of Kerala, the farmers prefer old trees for the selection of seed nuts, the farmers in the southern parts of Kerala collect seed nuts from young trees. The farmers in Assam and West Bengal select seed nuts from bulk harvests irrespective of age of the trees. Aiyer (1966) reported that in the erstwhile Mysore state, seed nuts were taken from trees between 25 and 30 years of age. The experimental evidence

is that age of mother palm has no influence on the performance of seed nuts (Anonymous, 1967). Since the heritability for yield in arecanut is low (0.20), substantial increase in yield could not be expected by direct selection in a given population (Bavappa and Ramachander, 1967). All the same, based on the available information and practices in vogue, certain minimum standards will have to be followed while selecting mother palms for seed nut collection. The important criteria that goes with the mother palm characters is its age at first bearing (Bavappa and Ramachander,1967, 1968) and regular bearing habit. Larger number of leaves on the crown, shorter internodes and high fruit set are the other desirable characters considered for selection of mother palm. Mother palms should be selected adopting the above criteria in each tract for meeting the processing and other end–product needs of the industry. Naidu (1962) opined that all cultivars are not suitable for preparing either *chali* or tender processed nuts.

2. Seed nut selection

The position of the bunch in the tree, the position of nuts in the bunch, the weight of nuts within a bunch, the maturity of the nuts and the floating habit of the nut are some of the factors considered by farmers for selection of seed nuts from selected mother palms. Nambiar (1949) and Aiyer (1966) reported that the common practice with the farmers is to select fully ripe seed nuts from the middle portion of the middle bunch in the tree (*i.e.*, the second and third bunches if there are four bunches). However, it was observed that the nuts selected from the middle portion of the middle bunch neither produced better seedlings, nor trees with better yield performance (Anonymous, 1963). There is no appreciable difference in germination percentage of nuts in the nursery among seed nuts ranging in maturity from $9\frac{1}{2}$ to $10\frac{1}{2}$ months (Anonymous, 1964). The nuts which float vertically with calyx–end pointing upwards when allowed to float on water are preferred, since the seedlings raised from vertically floating nuts are more vigorous than those float either slantingly or horizontally (Anonymous, 1964). About 25 per cent of nuts within a bunch are light in weight. The heavier nuts give higher percentage of germination (96 per cent against 87 per cent from lighter nuts) and produce seedlings of greater vigour. The percentage of quality seedlings is also higher from heavier seeds (Bavappa and Abraham, 1961).

In order to minimize damage to seed nuts, the bunches after harvest from the tree top are lowered to the ground by means of ropes in some parts of *Malnad* and *Maidan* of Karnataka. Naidu (1961) reported that lowering through rope

is unnecessary, since germination of seed nuts is not affected adversely when bunches are dropped to the ground. The advantage in lowering the bunch is probably in avoiding the scattering of nuts all over the ground which will involve extra labour in collecting the nuts.

3. Primary and secondary nurseries

For obtaining good germination, the seed nuts are sown as whole fruits, though half husked and fully husked nuts also germinate equally well (Anonymous, 1959). The mean number of days required for commencement and completion of germination are 53 and 94 respectively under Vittal conditions. About two per cent of the nuts do not germinate mainly due to embryo rot. The embryo is absent in 1.7 per cent of nuts (Bavappa, Patel and Bhat, 1957). About 1.5 per cent of the seedlings in the nursery die due to various other reasons. The number of days required for germination increases according to the altitude. At higher altitudes like Thirthahalli or Hirehalli, the number of days is more than those required at a lower altitude like Vittal.

The conventional practice with the cultivators is to sow the seed nuts after allowing them to dry for a couple of days under partial shade, preferably after smearing the nuts with cow dung (Nambiar, 1949; Aiyer, 1966). Sowing nuts immediately after harvest in soil or sand and watering once in two days result in early and good germination (Fig. 4B.1) (Bhat, 1956).

Farmers use several media/modes for sowing seed nuts. Seeds are sown in baskets mulched with straw or tied in banana leaf-sheath, straw (*muda*) or gunny bags and watered. Sand, soil or burnt earth (*Sudumannu*) are used as media for sowing. Bavappa (1956) found that sprouting the seed nuts in *muda* gives lower germination (85%) and less establishment (76%) in the nursery as against 96 per cent establishment in directly sown nursery. The seedlings of direct sown nuts are more vigorous than those from other methods like sowing in *muda* or baskets. Nuts when sown in the media should be vertical in position with the calyx-end just covered (Anonymous, 1964).

The sprouts are retained in the sand beds or primary nursery for about six months. Young seedlings at this stage with two or three leaves are transplanted to secondary nursery beds of convenient width and length. Beds of about 150 cm width and 15 cm height have been found convenient (Fig. 4B.2). The spacing of sprouts in the nursery has significant influence on the growth of seedlings (Bavappa and Mathew, 1960). Seedlings planted at wider spacing of 45 cm are more

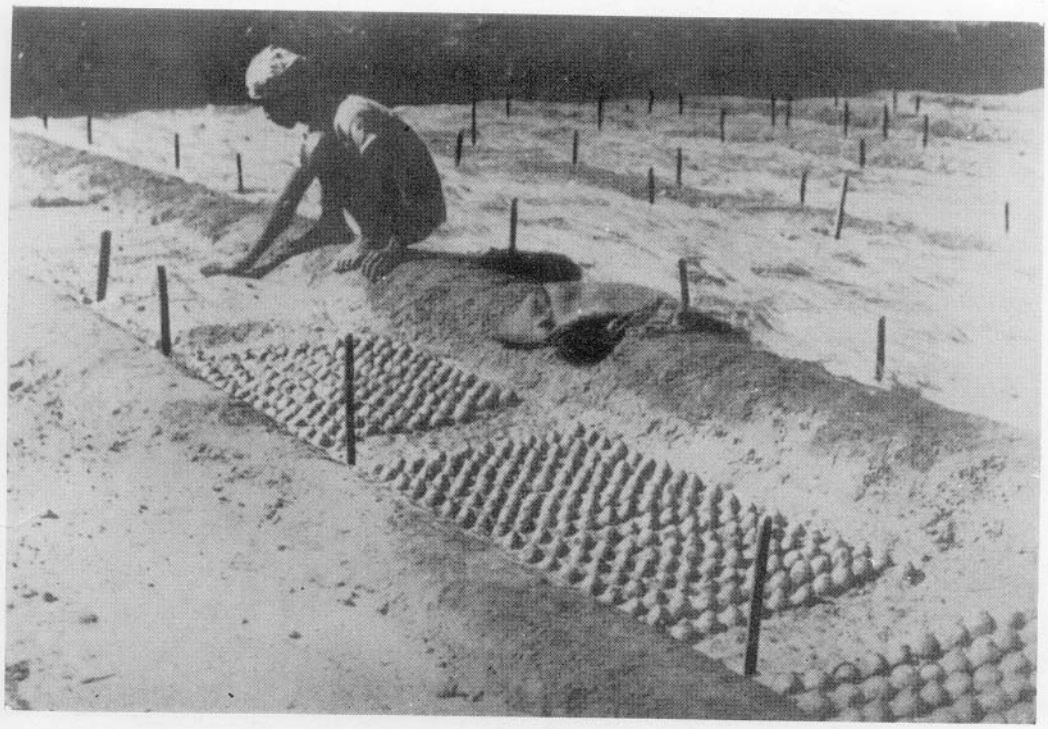

Fig. 4B.1 Sowing nuts in the primary nursery

vigorous than those planted at 15 cm. A spacing of 35–45 cm is considered to be optimum for a growth period of one year in the nursery. Instead of transplanting sprouts to the secondary nursery, they can as well be raised in polythene bags (Anonymous, 1962). Appaiah (1970) listed the advantages of polybag nursery which included a 15 per cent reduction in the seedling mortality. Arecanut sprouts and seedlings are very delicate and do not withstand exposure to direct sun. Bhat (1970) observed that the mortality of sprouts is 19 per cent in the open (fully exposed), while it is only one per cent in partial shade and only 0.13 per cent in fully shaded nurseries. The height, girth and number of leaves of seedlings in the open nurseries are significantly lower than those under shaded conditions, eventhough the percentage germination of seed nuts do not show any difference when sown either in the shaded or exposed nurseries. The percentage of quality seedlings is higher from shaded nurseries (Anonymous, 1969). The shade provided for the nursery may be either of coconut or arecanut leaves spread over a *pandal* (bower) or trailing *Coccinia indica* as overhead bower

Fig. 4B.2 Seedlings in secondary nursery

or quick growing green manure crops like *Sesbania* (Fig. 4B.3) in the nursery. Live shade may compete with arecanut for water and nutrients, but the advantage is the extra income the farmer gets from its produce (Anonymous, 1967). Sowing seed nuts in a primary nursery (with close spacing) and transplanting after about six months at a wider spacing in the secondary nursery is preferable for areas where the sowing season coincides with dry weather period (*i.e.*, December-February) and requires irrigation and shading. Paul (1960) recommended sowing seed nuts directly in 15 cm raised beds of 130 cm width at a spacing of 30 cm × 30 cm for the seed nuts in the sub-Himalayan region of West Bengal where the harvesting and sowing of the seed nuts coincide with the rainy season. As a shade crop for the nursery, either *Boga medeola* or *Crotalaria anagyroides* are suitable for those areas since these plants are perennial and thrive well under the low pH conditions of the region. For the *Maidan* parts of Karnataka, *Sesbania aegyptica* has been found to be the best (Naidu and Mashalkar, 1961).

Fig. 4B.3 Secondary nursery with green manure crop as shade

4. Selection of seedlings

Twelve to eighteen months old seedlings are transplanted in the main field. Seedling with maximum number of leaves (five or above) and minimum height are to be selected for planting (Bavappa, 1970). The selected seedlings are preferably removed with a ball of earth adhering to the roots for transplanting. Wrapping the base with the ball of earth in alkathene sheet/bag could keep the seedlings in good condition during long distance transport (Anonymous, 1964).

Seedlings of different ages (one to four years old) are used for planting in the permanent site in different regions (Nambiar, 1949; Aiyer, 1966). The practice of sowing the nuts *in situ* as well as transplanting are also in vogue (Nambiar, 1949). Palms raised from seedlings of one to two years old are more vigorous and flower earlier than those raised from seedlings kept for a longer period in the nursery. The cumulative yield of nuts from palms raised from one or two year old seedlings is also more than those raised from older seedlings (Anonymous, 1971b). Transplanting 18–30 month old seedlings is reported to be advantageous in Assam (Anonymous, 1971a).

III. Establishing the garden

1. Selection of site and layout

Arecanut is essentially a garden land crop and thrives best in humid areas protected well against hot sun-burn and heavy wind. The palm does not withstand either drought or water stagnation. The site selected should, therefore, have adequate irrigation facility (in places where the moisture available is not adequate) during the dry weather period.

The soil also should be well-drained or should have drainage facilities where the water table is very high. The arecanut palm is very delicate and cannot withstand extremes of temperature and exposure to direct sun. Under highly exposed conditions, the stem particularly in the young age, gets scorched up and permanently gets damaged. So it is essential that the site selected for raising arecanut garden should have protection from southern and western sides by way of either hillocks or tall ever-green trees. It is for this reason that the traditional gardens are located in valleys of hill slopes which are protected by forest trees growing all around. Such gardens are typical of the *Malnad* parts of Karnataka (Coleman and Rao, 1918) and parts of Kerala. In other areas like the *Maidan* parts of Karnataka where adequate natural protection is not available, the required condition is created by raising trees like coconut and mango and *Sesbania aegyptica*. The soil selected should be deep (preferably not less than two

meters) to ensure well developed root system. Under well-drained, deep soils, the roots traverse down to about three meters (Bhat and Leela, 1969), whereas under ill-drained condition and in places with higher water table, the roots confine to only about 1.40 m in depth (Bhat, 1978). Thus soil depth and water table are two important aspects to be considered while selecting site for arecanut plantation. If the site selected is on hill slope or valley, bench terracing is required to conserve moisture and prevent run-off of soil and manure.

Different methods of planting *viz.*, square, rectangular, triangular and quincunx are in vogue. Aligning the rows in north–south direction and planting on quincunx system lowers the incidence of sun-scorch (Anonymous, 1971a).

2. Spacing

The spacing of arecanut palms depends primarily on the depth and fertility of the soil. The spacing adopted in different arecanut tracts varies from 1.25m × 1.25m to 3.6m × 3.6m (Nambiar, 1949). The number of leaves shed and spadices and female flowers produced per palm invariably increase with increased spacing (Table 4B.1).

Table 4B.1. *The influence of spacing on yield attributes (palm/year)*

Spacing (m)	Leaf fall (no.)	Spadices (no.)	Female flowers (no.)	Percentage of fruit set
1.8 × 1.8	6.51	3.83	659.8	11.76
1.8 × 2.7	6.94	4.65	878.7	17.49
1.8 × 3.6	7.19	5.06	1025.4	19.42
2.7 × 2.7	7.53	6.01	1296.7	24.90
2.7 × 3.6	7.97	6.27	1289.0	27.65
3.6 × 3.6	7.78	6.14	1396.9	27.62
C. D. (P=0.05)	0.30	0.94	182.2	

Under Vittal conditions maximum yield (the number and weight of fruits) harvested per unit area is obtained from palms spaced at 2.7m × 2.7m (Bhat, Leela and Somaiah, 1972, cited by Bhat, 1978) (Fig. 4B.4; Table 4B.2). The results of the trial at Peechi also suggest 2.7m × 2.7m as optimum spacing in central Kerala area (Anonymous, 1974). At Hirehalli maximum number of nuts per unit area is from 1.8m × 3.6m spacing closely followed by 2.7m × 2.7m spacing. The weight of nuts is however maximum in 2.7m × 2.7m spacing followed by 1.8m × 2.7m spacing. The differences in the yield of nuts among 1.8m × 3.6m and 2.7m × 2.7m and 1.8m × 2.7m are not significant (Anonymous, 1976). At Kahikuchi (Assam), the

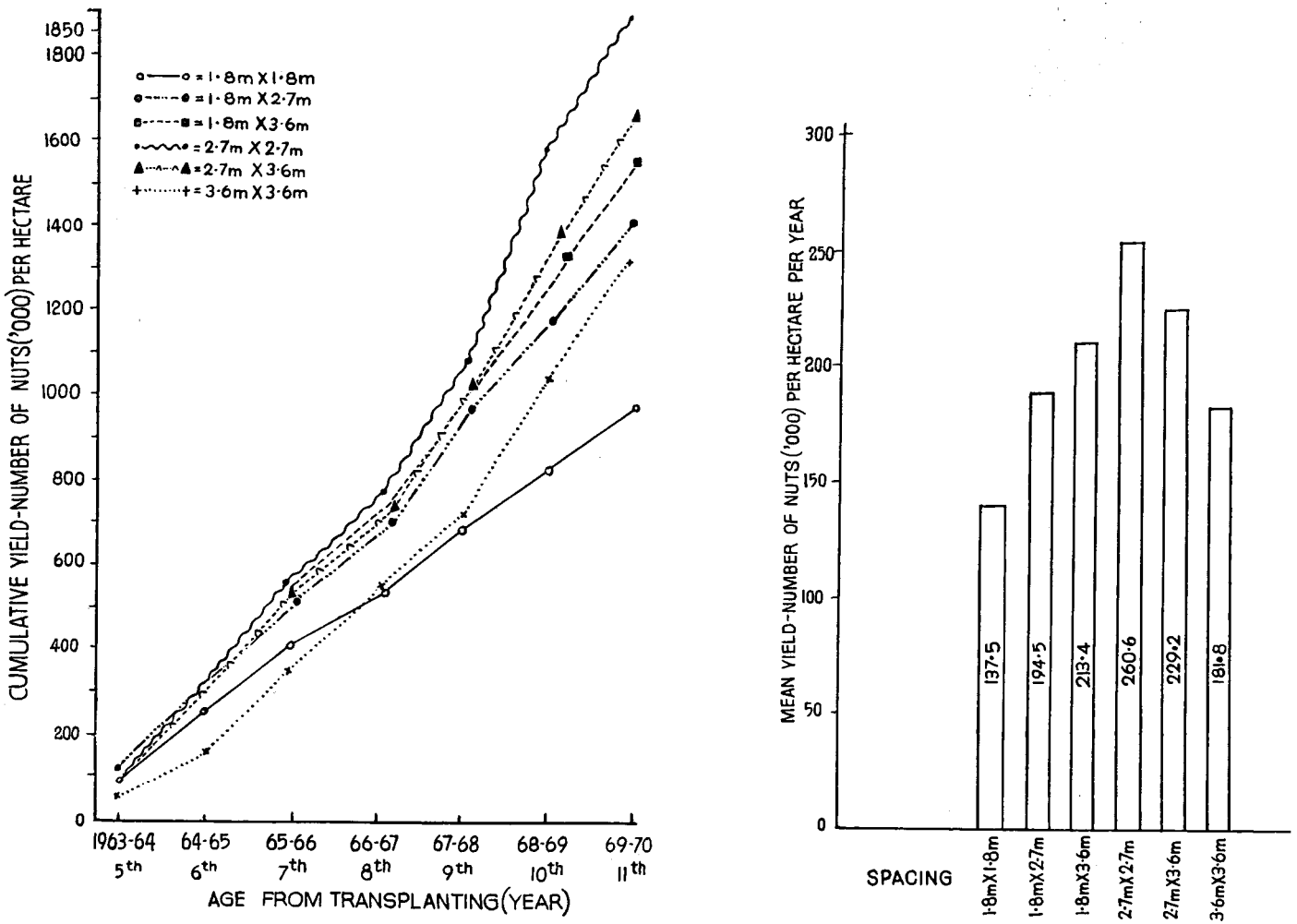

Fig. 4B.4 Relation between spacing and yield of arecanut

yield of nuts harvested per unit area is maximum in 2.7m × 2.7m spacing and is significantly higher to those obtained from 1.8m × 1.8m, 1.8m × 2.7m and 3.6m × 3.6m spacings (Anonymous, 1977).

Table 4B.2. *The relation between spacing and cumulative yield (first seven years at Vittal)*

Spacing (m)	Nuts/plot (10.8 m × 21.6 m)		Nuts/palm	
	No. ('000)	Wet weight (kg)	No. ('000)	Wet weight (kg)
1.8 × 1.8	17.16	587.01	0.312	10.67
1.8 × 2.7	21.83	726.12	0.662	22.01
1.8 × 3.6	21.30	730.57	0.968	33.21
2.7 × 2.7	27.92	1000.57	1.329	47.65
2.7 × 3.6	21.84	750.97	1.559	53.64
3.6 × 3.6	16.49	575.65	1.649	57.57
C. D. (P=0.05)	6.63	222.91	0.440	14.77

The study on the distribution of arecanut roots under different densities of planting reported by Bhat and Leela (1969) when considered along with the yield of individual palms and yield of nuts from unit area indicates that a spacing of 2.7m × 2.7m is optimum for arecanut palm. Under wider spacings, the exploitation of soils is not full whereas in closer spacing there is heavy concentration of roots in the lower layers of soil resulting in the marked reduction in yield. Thus from an overall assessment of the result, it is justifiable to adopt a spacing of 2.7m × 2.7m in majority of areas.

3. Depth of planting

The basic consideration in deciding the depth of planting is the sub-soil moisture and height of water table since arecanut palms do not withstand water stagnation. In well drained soils or in fields where drainage can be provided if required, deep planting is preferred. Deeper planting besides providing a firm anchorage to the roots also provides a larger volume of space for the spread of roots. Year-after-year, the fresh nodes exposed above the bole of the palm get covered up or earthed up as the pits get slowly filled up in the course of the annual operations of manuring and intercultivation. The nodes thus covered throw out fresh roots and ramify rapidly. Where deeper planting is not practical due to the high water table or other conditions of the soil as found in the typical high rainfall areas of the *Malnad* of Karnataka, seedlings are planted in the shallow pits or in extreme cases over mounds raised for the purpose. Under these conditions, the roots get exposed and require earthing up (Fig. 4B.5). The earthing up is achieved by spreading of fresh earth cut and transported from

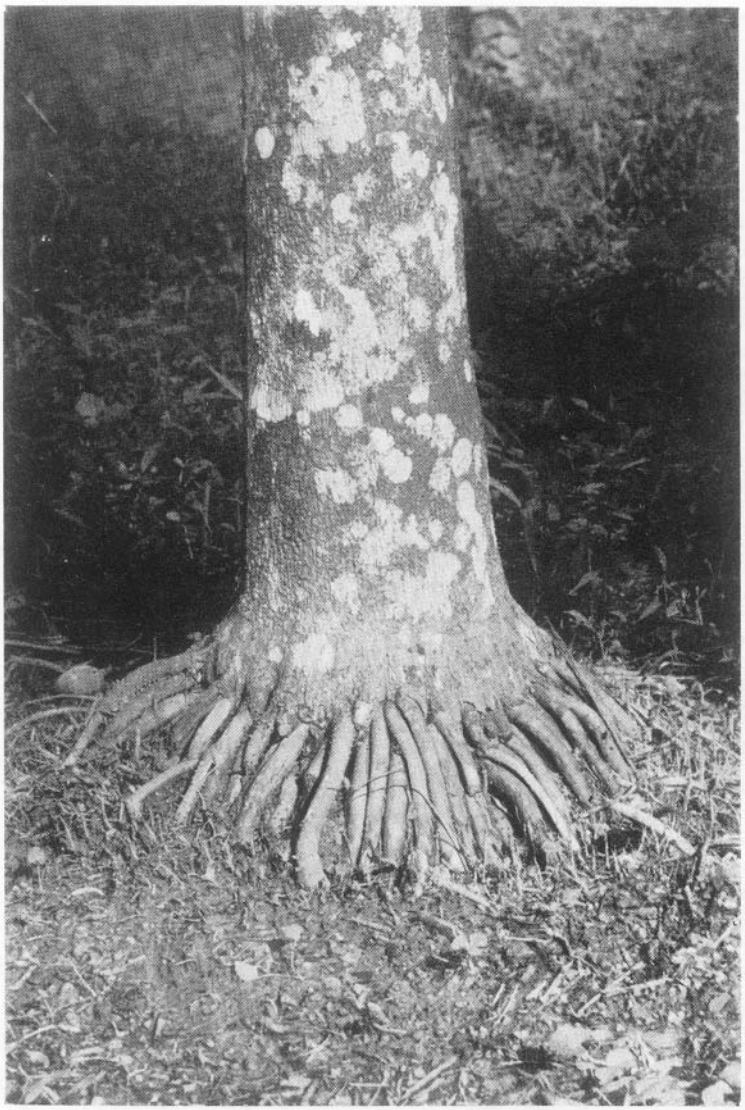

Fig. 4B.5 Surface roots due to shallow planting

nearby hillocks. This is a very laborious and costly operation. Experimental evidence shows that seedlings planted at 90 cm depth, are more vigorous and flower earlier than those planted at 30 cm and 60 cm depth (Bhat and Leela, 1968). The yield of palms also increases as the depth of planting increases from 30 cm to 90 cm (Table 4B.3) (Sadanandan, 1973). At Hirehalli and Kahikuchi, where the seedlings are planted upto 60 cm and 45 cm depth respectively, the

advantages of deeper planting is not appreciable, probably because of the heavier type of soils in those areas and added impedance for the proper drainage. Thus in soils where natural drainage can be provided (particularly during the heavy rainfall periods), deeper planting of seedlings upto 90 cm is preferred.

Table 4B.3. *Effect of intervals of irrigation and depth of planting on arecanut yield (Peechi)*

Treatments	Depth of planting							
	30cm	60cm	90cm	Mean	30cm	60cm	90cm	Mean
	No. of nuts/palm				Weight of nuts/palm (kg)			
No irrigation	1.73	1.62	21.89	8.41	0.05	0.04	0.72	0.27
Irrigation once in 3 days	121.66	179.80	278.49	193.32	3.56	5.49	8.27	5.77
Irrigation once in 6 days	67.35	108.53	204.84	126.91	1.82	3.09	5.99	3.63
Irrigation once in 9 days	91.64	112.89	165.89	123.47	2.74	3.57	4.64	3.65
Mean	70.67	100.71	167.78		2.04	3.05	4.91	
CD (P=0.05) for irrigation		45.04				1.18		
CD (P=0.05) for depth of planting		30.60				0.79		

4. Season of planting

Planting seedlings in the permanent site is done either in the months of May-June or September-October, depending upon the very heavy and in river banks where there is the likely danger of inundation, it is advisable to plant at the fag end of the South-West Monsoon in the month of September-October. In other places where the South-West Monsoon is not severe, planting may be advantageously done in May-June.

5. Drainage

The successful establishment of the seedlings and the performance of young palms depend on two important factors, *viz.*, perfect drainage and protection from sun-scorch. In order to ensure that adequate drainage is provided it is essential that one drainage channel is dug for every two rows of palms. The channels should be at least 15–30 cm deeper than the depth at which the seedlings are planted (Fig. 4B.6). At the beginning of monsoon each year these drains are to be cleaned to have an easy flow to stagnant water. Even the planted pits are to be provided with outlets and emptied to the drains.

6. Shading

During hot-weather period beginning from October, the young seedlings may be protected against direct exposure to sun by providing artificial shade of either arecanut or coconut leaves or by raising a shade crop of banana (Fig. 4B.7). Raising banana crop during the early years helps the farmer to get some income as the areca trees will take four or five years to give any revenue.

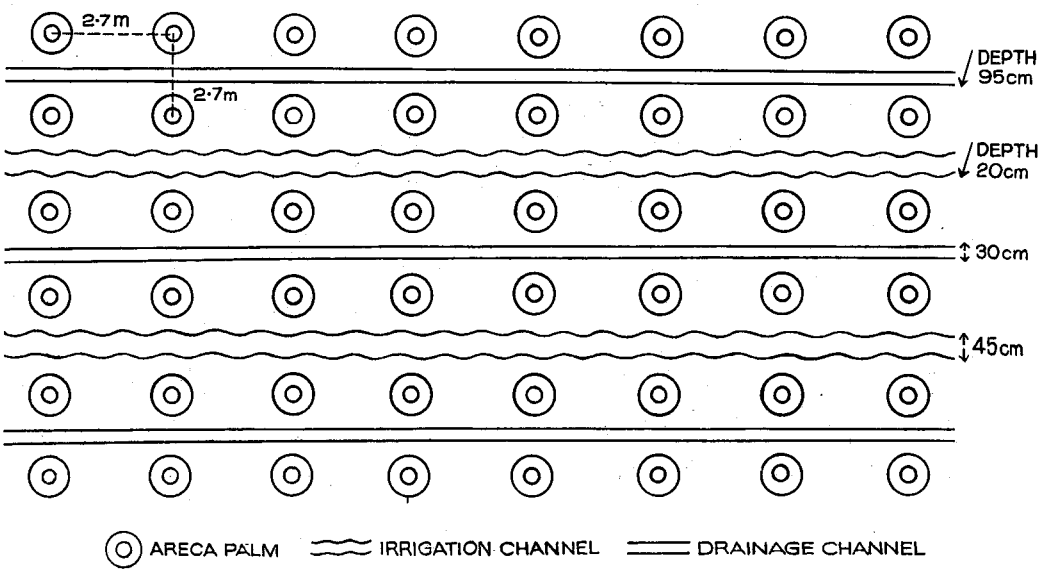

Fig. 4B.6 Lay-out of an arecanut garden showing irrigation and drainage channels

Protecting the stems of young palms from sun-scorch is also important since the part once lost or got damaged cannot be recovered. Sun-scorch is mostly seen during the months of October to January. Hence from the beginning of October the exposed stems of individual palms are to be protected by covering with materials like dry leaves of arecanut or white opaque polythene film (Bhat and Leela, 1968). When there is no natural protection, the exposure of palms to direct sun can be avoided by raising a belt of quick-growing trees on the western and southern aspects of the garden. If the soil moisture is not adequate or in places where there is dry spell, the palms are to be irrigated.

IV. Garden management

1. Cultural operations

The cultural practices followed by the cultivators in different parts of India differ widely. Both in the *Maidan* and *Malnad* parts of Karnataka, elaborate and programmed systems of cultivation are practised (Coleman and Rao, 1918). In the *Maidan,* digging is done twice a year, once in May-June and again in November-January. In a few places digging is done thrice a year. Farm yard manure is spread on the ground either before or after one of the diggings. Coleman and Rao (1918) did not favour spreading farm yard manure after digging, since the practice has a tendency to encourage surface roots which dry out during summer. In the

Fig. 4B.7 Banana as a shade crop to protect seedlings in the main field

Malnad the digging is done once in three years. In one year, digging and application of farm yard manure is attended to. In the second year, farm yard manure, green leaf or earth are applied without digging. During the third year no treatment is given. Aiyer (1966) also described a similar elaborate annual cultivation system involving four operations *viz.*, digging the ground at the base of trees, spreading farm yard manure over which twigs with green leaves brought from nearby *soppinabettas* (akin to agro-forests) are piled up about one meter high over the entire interspace and finally covering the twigs with fresh earth. The whole operation is very costly and laborious and hence is confined to one-third of the garden only. The next one-third portion of the garden receives only some of the items out of the four mentioned and the last one-third receives practically no attention except removal of weeds. The earth required for spreading over the leaves is heaped in the form of a mound of about 75-100cm high along the

middle of two rows of palms. The mound is built up of soil obtained by digging drains and by transporting soil cut from adjacent valley sides. The soil of the mounds get depleted slowly and in the course of 10-12 years get exhausted completely. The stock of soil required for future use is again made up by building fresh mounds over the space which was earlier occupied by drains in between the adjacent rows of palms. New drains are dug in the space where earlier soil mounds were running, thus bringing an interchange of position of mounds and drains. The cultivation practice is not so elaborate in the *Maidan* parts where the attention is more for removal of weeds, irrigation and conservation of moisture. The cultivation systems in the two contrasting situations of hills and valleys with torrential rainfall of *Malnad* tracts on one side and the open and flat tracts with limited rainfall of the *Maidan* on the other, are so well standardised by the cultivators depending upon the situation and needs of the crop in the respective tracts.

Hardly any such operations are carried out in Assam, parts of Kerala and West Bengal whereas in other parts of Karnataka and north Kerala the gardens are regularly cleared of all weeds and hoed once or twice a year. According to Nambiar (1949), experienced arecanut cultivators all over the country are of opinion that intercultivation increases productivity of palms by 10-20 per cent. During 1967-1975, experiments were conducted at the Research Centres in Peechi and Hirehalli to determine the role of different cultivation practices. At Peechi, there was no significant yield differences among the plots receiving different methods of intercultivation (no intercultivation; digging once in an year; digging twice in an year and digging once in two years). At Hirehalli, digging the garden twice a year (in June and December) had given higher yield of arecanut as compared to other methods, *viz.*, (1) scything grass and weeds twice a year (June and December); (2) digging once a year (December) followed by scything weeds (June); and (3) scything weeds twice a year (June and December) and digging once in two years (Table 4B.4) (Sannamarappa, Kumar and Nagaraj, 1976).

In southern Kerala where the gardens are not irrigated, the problem is to conserve soil moisture. A trial to study the effects of different methods of raising arecanut gardens on hill slopes with three systems of planting (planting on terraces made along the contours; planting on terraces made at the site of planting and planting on slopes not considering the contour) was carried out at Palode under rainfed conditions during 1961-1974. Each of the above three treatments had nine sub-treatments consisting of various combinations of cultivation, manuring and cover cropping.

Table 4B.4. *Effect of different methods of tillage on the yield of arecanut and yield components (Hirehalli)*

Treatments*	Year				Mean
	1971–'72	1972–'73	1973–'74	1974–'75	
			BUNCHES (No./palm)		
1	1.20	1.37	2.05	2.18	1.70
2	1.15	1.60	1.37	2.03	1.54
3	1.92	2.00	2.65	2.32	2.47
4	0.65	0.62	0.33	1.43	0.76
CD (P=0.05)	0.61	0.70	0.80	0.83	0.61
			NUT (No./palm)		
1	118.0	225.0	343.0	335.0	255.0
2	100.0	191.0	164.0	287.0	186.0
3	225.0	369.0	515.0	597.0	427.0
4	26.0	78.0	39.0	176.0	80.0
CD (P=0.05)	107.0	130.0	135.0	173.0	107.0
			WET WEIGHT OF WHOLE NUT (kg/palm)		
1	1.89	3.84	4.44	5.21	3.84
2	1.60	3.35	2.79	4.48	3.05
3	3.79	6.19	7.75	8.96	6.67
4	0.42	1.17	0.67	2.49	1.19
CD (P=0.05)	1.57	2.34	2.19	2.72	1.88
			LEAVES FALLEN (No./palm)		
1	4.5	5.8	6.1	5.8	5.5
2	4.3	6.2	5.6	5.9	5.5
3	5.1	6.7	6.3	6.5	6.2
4	3.4	5.9	3.8	5.8	4.7
CD (P=0.05)	0.8	NS	0.8	NS	0.7

*1. Scything weeds twice a year in June and December.
2. Digging once a year in December, followed by scything weeds in June.
3. Digging twice a year in June and December.
4. Scything weeds twice a year and digging once in two years.

The final results showed that clean cultivation and manuring once in two years (100g N + 40g P_2O_5 + 140g K_2O) gave the maximum yield closely followed by cover crops (cut and spread) plus manuring. Palms planted along the contour recorded highest yield. The production was minimum in palms planted on slopes without considering the contour (Anonymous, 1975).

Mulching the interspaces of arecanut gardens with green or dry leaves is a common practice in the *Malnad* and sub-mountane regions of Karnataka. The practice of spreading leaf with twigs in the heavy rainfall areas serves as a mulch, prevents evaporation from the ground recently dug, protects loose soils from erosion

during heavy rains and forms humus and manure to the soil (Coleman and Rao, 1918). In Dakshina Kannada district of Karnataka and parts of Cannanore district of Kerala, application of green leaf with twigs is confined to the base of the palm around a radius of about 50 cm. Some cultivators spread the interspaces of garden during the hot weather period with dry leaves collected from nearby *kumki* lands (*i.e.*, lands adjoining the farmers' lands earmarked for growing shrub jungle). In recent years, efforts are being made to utilize other waste materials like arecanut husk and chopped arecanut leaves as mulch (Anonymous, 1957). The plots spread with arecanut husk not only improved the texture of the soil but also helped to conserve moisture. A trial to compare four types of mulching materials (1) chopped arecanut leaves, (2) Guatemala grass *(Tripsacum laxum)* cut and spread, (3) arecanut husk, and (4) dry leaves collected from forest lands was conducted at Vittal. The loss of moisture from the mulched plots was considerably lower than plots without mulch. The weed growth was also suppressed in the mulched plots (Anonymous, 1967, 1969).

2. Manuring

Nambiar (1949) reported that manuring arecanut palm was practised only in parts of Karnataka, South Malabar of Kerala and to some extent in Coimbatore district of Tamil Nadu. In these parts, green leaves and cattle manure were being applied in large doses either annually or once in two or three years. The gardens in Mettupalayam get plenty of silt and soil through the irrigation water from Kallar and Coonoor rivers. Of late, the growers in this area are applying farm yard manure besides groundnut cake and fertilisers.

Coleman and Rao (1918) outlined the elaborate system of manuring with cattle manure and green leaves in the *Malnad* and use of tank or river silt or earth from paddy fields together with farm yard manure in *Maidan* parts of Karnataka. Aiyer (1966) also mentioned the extensive manuring system practised in the *Malnad* using green leaves cut from *soppinabettas*.

The first scientific attempt to determine the manurial requirement of arecanut crop was made at the Marthur Farm in Mysore (Karnataka) primarily with the objective of finding out the extent to which fertilisers could be used and thereby lessen the dependence on green leaves and cattle manure (Coleman and Rao, 1918; Iyengar, 1954; Aiyer, 1966). Aiyer (1966) reported that based on the experiments during 1920–1936 at Marthur, application of 10 cartloads of farm yard manure to be covered with earth and leaves at five cartloads per 400 palms was recommended. This was to be followed by application of a mixture of

90.9 kg groundnut cake, 36.4 kg of ammonium sulphate, 90.9 kg of concentrated superphosphate and 136.4 kg of potassium sulphate every third year. Iyengar (1954) summarizing the results of manurial experiments of Marthur Farm stated that the indications in general were that a garden once brought to good yielding condition may be manured once in three years and that an yield of over 876 kg can be obtained by an application of 56.0 kg nitrogen, 84.0 kg phosphoric acid and 112.0 kg potash per hectare using groundnut cake as a source of nitrogen.

The second set of experiments were commenced only during 1950 under the aegis of erstwhile Indian Central Arecanut Committee in the form of Simple Manurial Trials in cultivators' fields (Lakshmanachar, Biddappa and Paulose, 1966). The experiment was conducted in the sub-mountane and coastal regions of Kerala and Karnataka and plains of Karnataka, West Bengal and Assam. The N, P and K sources were ammonium sulphate, superphosphate and muriate of potash respectively. The levels of nutrients added were N at 22.7 kg and 45.4 kg, P_2O_5 at 18.1 kg and 36.3 kg and K_2O at 34.0 kg and 68.0 kg per 500 palms. The fertilisers were applied for three years, 1961–'62 to 1963–'64. In Kerala, the fertilised plots in the sub-mountane regions recorded on an average 20 per cent and in coastal regions 11 per cent increased yield during the experimental period, while during the post-experimental period, the increase in the mean yield in the fertilised plots was 52 per cent for sub–mountane and 24 per cent for coastal regions. In the sub-mountane region of Kerala, application of 22.7 kg of nitrogen, 18.1 kg of phosphoric acid and 64.0 kg of potash for 500 palms was found to be economical. In the coastal regions of Kerala and Karnataka, 22.7 kg of nitrogen, 18.1 kg phosphoric acid and 34.0 kg of potash for 500 palms was economical.

With the establishment of Central and Regional Arecanut Research Stations, comprehensive experiments to determine the manurial requirements of arecanut palms were laid out under different agroclimatic conditions at Vittal, Hirehalli, Thirthahalli, Peechi, Mohitnagar and Kahikuchi. The treatments consisted of N at 0, 50, 100 g; P_2O_5 at 0, 40, 80 g; K_2O at 0, 70, 140 g and green leaf at 0, 7, 14 kg per palm per year at all the centres except Mohitnagar. At Mohitnagar, treatment consisted of N at 0, 100, 200 g; P_2O_5 at 0, 40, 80 g and K_2O at 0, 140, 280 g per palm as main treatments and lime at 0 and 1 kg per palm as sub–plot treatment. At Vittal and Peechi, the doses were revised in 1971 to include higher levels (double the original levels) of nutrients. At Peechi, the revised schedule included lime as a sub–plot treatment. N and green leaf in the original levels increased the yield of nuts significantly over no

fertiliser at Vittal, Hirehalli and Kahikuchi. At Vittal, though there was increase in yield at higher levels of N (in the revised levels), the difference was not significant. The effect of green leaf application on yield of nuts was significant in most of the years and the maximum yield was obtained in the highest level of 21 kg per palm. Application of potash had significant effect on number and weight of nuts at Mohitnagar and Kahikuchi. Lime application at 1 kg per palm adversely affected the growth of palm as well as yield at Mohitnagar (Anonymous, 1977). Sadanandan (1972, cited by Bhat, 1978) reported that at Peechi nitrogen and green leaf application significantly and individually increased height, girth and leaf production while potash significantly increased only height and leaf production. N at 100 g and K_2O at 140g per palm individually increased the production of spadices and percentage of spadices to leaf fall, nut production and its relative weight significantly. N at 100 g per palm increased earliness in flowering significantly. The influence of P was not significant on any of the characters studied except on an initial increase of height and percentage of spadices to leaf fall. Green leaf at 14 kg per palm significantly increased spadices production, percentage of spadices to leaf fall and relative individual weight of nuts. In the revised schedule, green leaf at 21 kg per palm increased significantly the number of nuts than at 7 kg per palm (Anonymous, 1976).

Another experiment to determine the effect of applying the nutrients N, P and K in organic and inorganic forms on the performance of palms was carried out at Vittal during 1963–1969. The yield data for the various years showed no significant difference between the two forms of nutrients (Anonymous, 1971a). Based on the results of the manurial trials, annual application of 100g N, 40g P_2O_5 and 140g K_2O in the form of fertilisers and 12kg each of green leaf and compost per bearing palm is recommended. Fertilisers are applied in basins around the palm dug to a depth of 15–20 cm and 0.5–1.0 m radius leaving 20 cm from the base of the palm (Fig. 4B.8). After application, the soil is rolled up and covered with organic matter (green leaves/compost) and soil.

Application of fertilisers in split doses in March-April and September-October did not show any significant effect on yield under central Kerala (Peechi) conditions (Anonymous, 1976).

3. Irrigation

Arecanut palm is very sensitive to drought. Irrigation is essential in areas with long dry spell. In places with high sub-soil moisture and in areas where the rainfall is well distributed, throughout the year no irrigation is practised. In West

Fig. 4B.8 Manuring arecanut palm

Bengal, Assam, northern parts and southern parts of Kerala, the crop is grown as rainfed crop. In certain parts of Kerala and Karnataka the arecanut gardens are irrigated. In the traditional system, wherever irrigation was required the source of water was tanks situated at the head of gardens from where the water used to be guided by gravitational flow. Later lift irrigation from wells and rivers came into practice. Presently large number of gardens are being irrigated using pump sets run by oil or electricity. Deep bore wells as source of irrigation water is also being tapped in recent years.

The methods of irrigation are also undergoing changes. In the traditional system, irrigation is done by bunding and storing the water in the drainage or irrigation channels and water is allowed to percolate. Irrigation in a majority of the gardens is by splashing water guided into channels (Fig. 4B.9). In recent years sprinkler (Fig. 4B.10) and perfo methods of irrigation are slowly entering into practice. Drip or trickle irrigation method is still in experimental stage.

Fig. 4B.9 Splash irrigation in arecanut garden

Experiments on the irrigation requirement of arecanut and on the frequency of irrigation were initiated at Peechi, Hirehalli, Mohitnagar, Kahikuchi and Vittal from early 1960. At Peechi, all irrigation treatments led to substantial yield increases, the 3-day interval being better than 6 and 9 days intervals (Table 4B.3) (Sadanandan, 1973). According to him, the water requirement of arecanut during four dry months was 82.5 cm. At Vittal, where four intervals of irrigation (5, 10, 15 and 20 days) were tried (between 1966 and 1972), irrigations at intervals of 5 and 10 days were superior throughout.

The irrigation schedules at Vittal were modified in 1973–'74 and the treatments were based on cumulative potential evaporation (CPE). The results showed that an irrigation of 30 mm depth when CPE is 30 mm is the best. At Kahikuchi, where three intervals of irrigation *viz.*, 7, 14 and 21 days with no irrigation were tried, the closer intervals of irrigation, *viz.*, once in 7 days

Fig. 4B.10 Sprinkler irrigation in arecanut garden

and 14 days, showed superiority over irrigation once in 21 days or no irrigation. At Hirehalli, where four intervals of irrigation, (5, 10, 15 and 20 days) were under comparison, there was no significant difference among the treatments (Anonymous, 1969, 1970, 1971a, 1971b, 1976, 1977). At Palode where arecanut gardens are normally not irrigated, irrigation increased the yield by 2–3 times (Anonymous, 1976). Experiment with a view to economising in the use of water by adopting drip irrigation method has been conducted at Vittal during 1978–'80 by Khader (Personal communication). He reported that drip irrigation system improved the soil water regime by minimising the fluctuations in the soil water content, minimised weed growth and increased yield significantly.

V. Harvesting

The stage of harvesting depends upon the type of produce to be prepared for the consuming markets. There are two main types *viz.*, one prepared out of immature green nuts and the other from ripe nuts. In each case the maturity at which the fruit is harvested and the season of harvest affect the quality of the

Fig. 4B.11 Lowering harvested arecanut bunch by a rope

processed nut considerably. Trials conducted at Peechi showed that the proportion of *vellai choor,* which fetches higher price than other trade varieties like *choor kora,* was more when the fruits were harvested at six months maturity level than harvested at higher maturity level of seven months (Anonymous, 1971a). In another study, it was found that the quality and quantity of kernel *(chali)* processed out of fully

ripe fruits were much better than those fruits which were not fully ripe. The former gave 8.6 per cent increase in weight of *chali* and fetched 72 per cent more price than *chali* from less mature (ripe) fruits (Anonymous, 1969). The above contingency arises when two successive bunches are harvested simultaneously, which have different maturity level.

Fig. 4B.12 Climber swinging from one palm to another for harvesting

Various methods are followed for harvesting arecanut bunches. In regularly spaced garden, the climber climbs a tree at one end of the garden, harvests the bunch and sends it down by a rope (Fig. 4B.11) or gunny bag or drops down the bunch to the ground. The climber pulls the nearest palm with the help of a hook and swings to it (Fig. 4B.12). It is not uncommon to see a climber harvesting 50–100 palms or even more, by swinging from one to the next, at a stretch before coming down to the ground. In certain parts of north Kerala and Dakshina Kannada areas of Karnataka, a long bamboo with a sharp sickle or hook attached to the end is also being used for harvesting the bunches. It is reported that monkeys specially trained for the purpose harvest arecanut bunches in Malay (Nambiar, 1954).

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5

MULTIPLE CROPPING

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Multiple cropping in arecanut garden as a productive land use system has received much attention in the recent past. It is practised mainly through the use of interspaces for growing other crops of shorter duration. More than three decades ago Bavappa (1951) reported the mixed cropping or intercropping of banana, betelvine, tapioca, black pepper, colocasia, yams, pineapple, jack and coconut in arecanut garden. Abraham (1956) also indicated the successful cultivation of crops like ginger, turmeric, black pepper and cardamom in arecanut gardens. The long pre-bearing age of the main crop, small income from initial harvests, insecurity against pests and diseases, remoteness from markets and lack of transport were considered to be some of the reasons that might have prompted farmer to grow different crops in arecanut garden (Abraham, 1956; Naidu, 1959; Khader and Antony, 1968; Bhat, 1974; Nagaraj, 1974). The choice of the crop combination varied with family needs also.

I. Different forms of multiple cropping with arecanut

Three different forms of multiple cropping are generally recognized, *viz.*, intercropping, mixed cropping and mixed farming.

1. Intercropping

Intercropping means growing two or more crops simultaneously on the same field. According to Nelliat and Iyer (1977) intercropping as applied to plantation crops refers to growing annuals or biennials in the interspaces of the

main crop. It indicates that no distinction is made regarding the planting pattern and row arrangements, though some workers (Freyman and Venkateswaralu, 1977; Beets, 1978) considered that intercropping should imply a definite planting pattern of the component crops in separate rows.

i. *Raising the intercrops*

A large number of crops like paddy, sorghum, cowpea, vegetables, yams, pineapple, banana, etc. are grown by the farmers as intercrops in arecanut gardens. However, their suitability and cultural requirements as intercrops are not fully investigated so far. In the absence of adequate experimental evidences, most workers (Khader and Antony, 1968; Bhat and Khader, 1970; Abraham, 1974; Bhat, 1974; Thomas, 1978; Muralidharan, 1980) have followed the package of practices prescribed for these crops under their pure culture. The planting in cultivators' fields is mostly irregular but in systematic field experiments they are planted in definite patterns and proportions. Every palm is given a circular area of about 0.75 m – 1 m radius to facilitate cultural operations like opening basins, application of fertilisers and manures, irrigation etc. The interspaces are dug or ploughed when the pre-monsoon showers are received to prepare the land for planting the intercrops. Crops like paddy (usually a shade tolerant upland variety called 'chennellu'), *Sorghum,* corn, cowpea and groundnut are sown (dibbled) in furrows. Pits or trenches are taken for crops like *Dioscorea,* elephant foot yam, taros, pineapple and banana. Crops like ginger, turmeric (Fig. 5.1) arrowroot, chillies, etc. are planted in raised beds of convenient size as recommended for the particular locality.

ii. *Productivity of intercrops and their economic returns*

Field experiments were conducted at various research stations to compare the economic returns from intercropping in arecanut garden and it was observed that the productivity and economic returns vary widely, under different agro-climatic and socio-economic conditions (Table 5.1).

Muralidharan (1980) investigated the productivity of 19 crops as intercrops in arecanut *vis-a-vis* their sole crops at the CPCRI Regional Station, Vittal, and observed that the biomass productivity of the intercrops was significantly lower than that of the corresponding sole crops (Table 5.2) except in banana and beans.

The reduction in the productivity of intercrops varied from 18 per cent under beans to as much as 87.7 per cent under fodder *Sorghum.* Arrowroot

Fig. 5.1 An intercrop of turmeric in arecanut garden

Table 5.1. *Productivity and profit from intercrops in arecanut garden*

Location	Intercrop	Yield (kg/ha)	Net profit (Rs/ha)
Vittal	Arrowroot	4000	1000
	Elephant foot yam	12000	1550
	Banana	4000	1650
	Paddy	396	–319
	Ground nut	807	789
Palode	*Dioscorea*	6744	1824
	Elephant foot yam	6496	1700
	Tapioca	10246	1851
	Sweet potato	712	61
	Pineapple	3942	847
Kahikuchi	Banana	12200	728
	Pineapple	15700	2379
	Ginger	9800	998
Kannara	Ginger	2650	905

Table 5.2. *Biomass productivity of different crops as intercrop and sole crop*

Crops	Biomass (kg/ha)		Difference (y—x)	IC/SC %
	As intercrop (IC)	As sole crop (SC)		
	1978–'79 (x)	1978–'79 (y)		
Paddy	1425**	3691	2266**	38.6
Finger millet	1075*	6560	5485**	16.3
Sorghum	2041	10633	8592**	19.1
Maize	2704*	10546	7842**	25.6
Ground nut	1397	4776	3379**	29.2
Beans	105	128	23	82.0
Cowpea	698	2403	1705**	29.0
Dolichos	1072	3370	2298**	31.8
Yam	5046**	13750	8704*	36.6
Arrowroot	6580	9852	3272*	66.7
Dioscorea	4078	12241	8163**	33.3
Colocasia	2191	5647	3456**	38.7
Sweet potato	1819	9904	8085**	18.3
Ginger	2116	5498	2882**	47.5
Chillies	1014	2281	1267**	44.4
Turmeric	3287	8682	5395**	37.8
Fodder sorghum	1183	9616	8433**	12.3
Hybrid napier	9515	31360	21845**	30.3
Banana	5956	10137	4181	58.7

* Significant at P = 0.05 ** Significant at P = 0.01

and banana suffered only less than 50 per cent reduction, while ginger, chillies, colocasia, paddy, turmeric, yam and *Dioscorea* produced between one third to one half of their sole crop biomass. The remaining nine crops suffered severely under the intercropping system.

iii. *Effect of intercropping on arecanut*

Experimental evidences, in general, indicated that intercropping in arecanut was not harmful to the main crop (Muralidharan and Nayar, 1979). A number of field experiments were conducted at different research stations of the CPCRI to assess the effect of intercropping on the productivity of arecanut. Abraham (1974) reported that no perceptible deleterious effect on the yield and condition of arecanut palm could be observed due to intercropping with tapioca, elephant foot yam, yam and sweet potato (Fig. 5.2). Similar results were reported by Sadanandan (1974) on intercropping with elephant foot yam and ginger. A comparative statement of different reports on the effect of intercropping on the yield of arecanut is given in Table 5.3.

Fig. 5.2 An intercrop of sweet potato in arecanut garden

Table 5.3. *Effect of inter and mixed cropping on yield of arecanut*

Inter or mixed crop	Fresh weight of nuts (kg/palm)		Difference in yield over pure crop of arecanut (%)
	Control	With other crops	
Vittal			
Banana	9.9	9.1	— 8.5
Banana (first three years only)	5.2	6.6	+26.3
Kahikuchi			
Ginger	9.0	10.3	+14.4
Banana	9.0	7.9	—12.2
Pine apple	9.0	8.9	— 1.1
Guinea grass	9.0	10.4	+15.5
Ginger	9.9	10.3	+ 4.0
Betelvine	9.9	9.4	— 5.1
Kannara			
Black pepper	10.4	10.1	— 2.9
Thirthahalli			
Black pepper	13.3	6.1	—54.1
Cardamom	13.3	8.3	—37.6

Banana is a very popular intercrop in arecanut gardens (Fig. 5.3) (Sundaramurthy, 1950; Bavappa, 1951; Bhat, 1974; Brahma, 1974). A detailed study to investigate the long term effects of intercropping banana in arecanut garden planted at 2.7m × 2.7m was undertaken at the CPCRI Regional Station, Vittal, since 1963. The mean yield of arecanut over a period of six years from the fifth year of planting did not show any significant difference due to intercropping with banana under different intensities of planting (Table 5.4).

Fig. 5.3 An intercrop of banana in arecanut garden

Roy (1974) reported that the yield of arecanut grown in the alluvial soils of North-Eastern India was not significantly influenced by intercropping with banana. Similar results were also observed by Nagaraj (1974) and Bhandary (1974). However, significantly adverse effect of intercropping with banana on the yield of arecanut was observed in the experiments conducted at CPCRI, Research Centre, Hirehalli (1972–1980) and Kahikuchi (1973–1978). Though the yield of arecanut was reduced by growing banana as intercrop, it still remained as a profitable intercrop, since the income from banana alone was Rs. 4047.60 per ha at the market rates during 1980 at Hirehalli. Earlier workers also reported net

profits ranging from Rs. 728 to Rs. 1650 per ha as reviewed by Muralidharan and Nayar, (1979). Studies conducted at CPCRI Research Centre, Kannara, to select the best variety of banana for intercropping with arecanut have indicated that 'Mysore Poovan' gave the highest yield (Anonymous, 1981).

Table 5.4. *Effect of continuous growing of banana as intercrop on yield of arecanut (1975–'76)*

Treatments	Number of nuts/palm	Wet wt. of nuts (kg/palm)
Control (pure crop of arecanut at 2.7 m × 2.7 m)	144.7	5.24
Banana throughout the experimental period at full level *i.e.*, 1:1	102.7	3.83
Banana at full level for three years and no banana thereafter	182.9	6.62
Banana at full level for three years and at reduced level for the rest of the period	134.5	4.83
Banana at full level for three years and at reduced level for next three years	130.2	4.57
Banana at full level for six years and no banana thereafter	136.4	5.14
Banana at full level for six years and at reduced level thereafter	143.2	5.32
Banana at full level for six years, reduced level for next four years and no banana thereafter	140.2	5.09
CV (%)	31.4	32.0

2. Mixed cropping

The term mixed cropping is used to denote growing perennial crops in the interspaces of plantation crops like coconut and arecanut, (Nelliat and Iyer, 1977). Watt (1892) reported that tree crops like coconut, citrus, jack etc. were grown in arecanut gardens of the erstwhile Mysore State. In Kerala, especially in southern districts, arecanut is seldom grown as a pure crop. A large number of tree crops are grown with it due to compelling socio-economic situations resulting in overpopulated polyculture. However, the search for parallel combinations of compatible species is of recent origin. A number of field experiments were initiated at the CPCRI Regional Station, Vittal and other Research Centres and conclusive results are emerging on the suitability of different crops like cocoa, black pepper, coffee etc. for mixed cropping with arecanut.

i. *Mixed cropping with cocoa*

Preliminary studies initiated during 1964 at CPCRI Regional Station, Vittal indicated that cocoa can be an ideal combination with arecanut (Fig. 5.4). (Bhat and Leela, 1968). Bhat (1978) presented conclusive evidences on the positive performance of cocoa–arecanut mixed cropping system (Table 5.5).

The mean yield per arecanut palm in the mixed cropping experiment (arecanut and cocoa at 50:50) was higher than that of arecanut as a monocrop.

The gross annual income from the mixed garden, based on market prices between 1973 and 1975, was Rs. 18,949 per ha as compared to Rs. 13,083 per ha from the pure plantation of arecanut (Table 5.6) (Bhat, 1979).

Fig. 5.4 Mixed cropping of arecanut and cocoa

Table 5.5. *Yield of cocoa and areca mixed garden (1964 planting)*

Year	Treatments	Cocoa	Areca	
		No. of pods/plant	No. of nuts/palm	Weight of nuts/palm (kg)
1970–'71	1	64	225	7.7
	2	–	170	6.8
	3	36	125	4.4
1971–'72	1	50	322	12.2
	2	–	169	6.8
	3	17	233	8.0
1972–'73	1	77	391	13.3
	2	–	210	7.5
	3	22	242	8.3
1973–'74	1	107	230	8.4
	2	–	130	8.4
	3	40	124	4.3
1974–'75	1	95	314	11.4
	2	–	270	10.0
	3	41	267	9.3

Treatments: 1 – Areca and cocoa (50:50)
2 – Pure plantation of areca
3 – Cocoa as a border crop in areca garden

Table 5.6. *Yield and gross income from areca-cocoa mixed garden and pure areca garden*

Particulars	Yield in the mixed garden		Yield in pure plantation of arecanut
	Cocoa	Areca	
Number of fruits per tree	78	296	187
Number of trees per ha (4m × 4m)	625	625	1250
Estimated number of fruits ('000/ha/year)	49	185	134
Estimated dry weight (kg) of cocoa beans or arecanut kernel/ha/year	1225	1482	1869
Estimated value of produce/ha/year (Rs.)	8575*	10374**	–
Gross income (Rs.)	18949		13083

* Cocoa at Rs. 7.00 per kg
** Arecanut at Rs. 7.00 per kg

Based on the encouraging results of the preliminary studies, a detailed experiment was started at CPCRI Regional Station, Vittal to determine the optimum spacing and manurial requirements of cocoa under mixed cropping with arecanut. In this study *Forastero* variety of cocoa was planted with local cultivar ('South Kanara') of arecanut under six different spacings (Table 5.7) and two fertiliser

levels (M_1=100g N: 40g P_2O_5: 140g K_2O/arecanut palm and 200g N: 80g P_2O_5: 280g K_2O/cocoa plant). The yield of areca per ha was maximum at a spacing of 2.7m × 2.7m with cocoa at 5.4m × 5.4m and the yield of cocoa per ha was maximum at a spacing of 3.3m × 3.3m with areca also at 3.3m × 3.3m. The combined yield of areca and cocoa per ha was maximum when both were spaced at 3.3m × 3.3m (Bhat, K. S., 1982, personal communication) (Table 5.7).

Table 5.7. *Areca-cocoa mixed cropping–mean yield (wet weight of fruits) of three years (1978–'79 to 1980–'81)*

Spacing Areca / Cocoa	Mean yield/tree/year (kg)		Mean yield/ha/year (kg)		
	Areca	Cocoa	Areca	Cocoa	Areca+cocoa
2.7×2.7 m	4.78		6562		
2.7×2.7 m		13.98		19,119	25,745
2.7×2.7 m	5.46		7490		
2.7×5.4 m		24.27		16,647	24,137
2.7×2.7 m	6.70		9186		
5.4×5.4 m		27.28		9,357	18,543
3.3×3.3 m	6.76		6212		
3.3×3.3 m		22.41		20,575	26,787
3.9×3.9 m	6.36		4184		
3.9×3.9 m		22.13		14,553	18,737
1.8×5.4 m	5.83		5995		
3.6×5.4 m		26.19		13,470	19,465
CD (P=0.05)	1.37	6.62	1564.6	3735.8	(not tested)

Another experiment started in 1969 at CPCRI Research Centre, Kannara with six cross combinations of cocoa, two levels of fertiliser application (100g N: 40g P_2O_5: 140g K_2O and 200g N: 80g P_2O_5: 280g K_2O) and two methods of alignment (quincunx and square) did not show any significant difference between any of the treatments. The arecanut yield was in no way affected by mixed cropping with cocoa. Based on the results of these trials, cocoa is now recommended as an ideal crop for mixed cropping with arecanut.

For raising cocoa in arecanut garden pits of 75 cm^3 are dug at 2.7m apart in between alternate rows of standing arecanut palms and filled with top soil and

compost. The cocoa seedlings are planted with the onset of monsoon showers. In gardens where shade is insufficient, the cocoa seedlings are provided with artificial shade. When new gardens are established, arecanut can be planted at 3.3 m apart and cocoa seedlings planted at the centre of four arecanut palms (quincunx method). In such cases both arecanut and cocoa should be given adequate shade by growing intercrops like banana. Training and rest of the cultural operations for cocoa as an intercrop is the same as that for a pure crop.

ii. *Mixed cropping with black pepper, cardamom and tree spices*

Among the many perennial crops grown with arecanut, black pepper and cardamom are very important (Abraham, 1956). Net income ranging from Rs. 255 (Abraham, 1974) to as high as Rs. 17,666 per ha, (Anonymous, 1977) was reported from mixed cropping of black pepper with arecanut. In many parts of Kerala and Karnataka arecanut palms are used as live standards for training black pepper (Fig. 5.5).

Nayar (1982) recommended the black pepper hybrid *Panniyur-1* for well-spaced (2.7m × 2.7m) arecanut gardens where the infiltration of light is higher and 'Karimunda' for more densely planted gardens.

When black pepper is grown on arecanut, the manurial and fertiliser dose applied to arecanut should be doubled. Each palm should receive in addition to its normal recommended dose of 10 kg of farm yard manure or compost, 100g N, 40g P_2O_5 and 140g K_2O, an equal additional dose of manures and fertilisers to support the pepper crop starting from the third year of planting. During the first and second years, $\frac{1}{3}$ and $\frac{2}{3}$ respectively of the additional dose of manures and fertilisers should be applied. Application of lime at the rate of 500 g per standard during April–May in alternate years is reported to be beneficial (Nayar, 1982).

Nayar (1982) reported that the advantages of training black pepper on arecanut palms are not fully exploited by most of the farmers due to the fear that growing black pepper on arecanut may depress the yield of arecanut as well as the yield of black pepper. Experimental data from a mixed crop of arecanut and black pepper for a duration of 10 years showed that there was no significant detrimental effect on the yield of arecanut palms due to training black pepper on them (Table 5.8). Further it helped to augment the net income of the farmer by about Rs. 8,940 per ha from black pepper alone.

Bhandary (1974) reported that the yield of arecanut was lowered by 54.4 per cent due to mixed cropping with black pepper, though the yield of pepper had compensated the loss of revenue from arecanut. However, it was not known whether pepper received adequate manuring in this trial.

Fig. 5.5 Mixed cropping of arecanut and pepper

Table 5.8. *Yield of arecanut (mean of 80 palms) from the arecanut–black pepper mixed garden*

Period	Yield of arecanut/palm			
	Arecanut alone		Arecanut+pepper	
	No. of nuts	Fresh wt. of nuts (kg)	No. of nuts	Fresh wt. of nuts (kg)
1969–'70	225.7	7.5	207.0	6.90
1970–'71	303.0	10.0	265.3	8.8
1971–'72	370.0	12.6	366.3	12.2
1972–'73	267.6	8.9	256.6	8.4
1973–'74	280.0	9.3	278.8	9.0
1974–'75	225.9	7.5	240.7	8.2
1975–'76	275.4	9.1	280.8	9.6
1976–'77	418.7	13.6	413.0	13.0
1977–'78	362.5	12.8	376.9	12.1
1978–'79	373.0	12.4	381.9	12.7
Mean	310.2	10.4	306.6	10.1

Instances of cardamom being grown as a suitable mixed crop with arecanut were reported by Abraham (1954) and Bhandary (1974). Cardamom is planted under the shade of arecanut in the lower valleys of certain cardamom plantations at 1.5–2 m apart in between arecanut palms. Though precise data are not available on the yield performance of cardamom under such a system, the cardamom appeared to have no adverse effect on the yield of arecanut. Package of practices for both the crops should be followed for sustaining their yield at a high level.

Tree spices like cinnamon, clove and nutmeg are often grown in arecanut gardens. In a mixed cropping experiment with cinnamon conducted at CPCRI Research Centre, Hirehalli, the yield of arecanut increased from 17,892 kg per ha to 24,445 kg per ha within a period of three years, a 36.6 per cent increase over the pre-experimental yield of arecanut. In this experiment one year old cinnamon seedlings were planted at a spacing of 2.7m × 2.7m *i.e.*, in 1:1 proportion with arecanut (Fig. 5.6). The seedlings were planted in pits of 45 cm^3 filled with top soil and compost. The garden was irrigated. Clove is a high cash value tree spice that can be grown as a mixed crop in arecanut plantation at a spacing of 5.4m × 10.8 m.

iii. *Mixed cropping with other perennials*

Of the many other perennial crops that can be grown in arecanut gardens, atleast two, *viz.*, betelvine and coffee (Fig. 5.7) require special consideration. Roy

Fig. 5.6 Mixed cropping of arecanut and cinnamon

(1974) reported that an additional income of Rs. 3691 per ha can be obtained from growing betelvine in arecanut gardens. There was five per cent reduction in the yield of arecanut due to growing betelvine (Anonymous, 1977). Experiments conducted at Kahikuchi and Hirehalli also support this view, indicating that there was no significant difference between the yield of arecanut under monoculture and mixed cropping with betelvine (Roy, 1974).

Preliminary studies on mixed cropping arecanut with four varieties of coffee, *viz.*, *arabica* S–6, *arabica* S–1936, San Ramon and *robusta* at the CPCRI Research Centre, Hirehalli showed an yield increase of 12.9% in arecanut.

II. Advantages of multiple cropping in arecanut

The advantage of multiple cropping in arecanut (as in any other multiple cropping system) is the ability to provide substantial yield increase per unit area through better utilization of resources like land and light.

Fig. 5.7 Mixed cropping of arecanut and coffee

Bhat and Leela (1968) found that more than 80% of the roots of arecanut are within a radius of 75 cm from the base in palms spaced at 2.7m × 2.7m. The normal cultural operations are also confined within about 75–85 cm radius from base. Thus, the arecanut palms exploit only 2.27 sq. m. of (r=0.85m) land area out of 7.29 sq. m. (2.7m × 2.7m) land available to each palm. This estimate indicates that about 68.9 per cent of land is not effectively utilized by the root system of arecanut palm. Multiple cropping system in the arecanut garden can more effectively utilize this unused land volume.

Muralidharan (1980) reported that 32.7–47.8 per cent of incident light rays pass down through the canopy of a 14 year–old arecanut garden depending on the time of the day. Normally in a pure arecanut crop spaced at 2.7m × 2.7m, this light energy reaches the ground and wasted. Multiple cropping in arecanut garden can advantageously utilize this energy.

The tremendous potentialities of multiple cropping in coconut and arecanut plantations to generate employment opportunities for improving the quality of rural life has been indicated by Nair and Bavappa (1975). Apart from increasing the production of additional crops and employment potential, multiple cropping system can act as a social security against instability of yield such as crop loss due to severe incidence of *Mahali*.

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6

PESTS

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Arecanut palm, *Areca catechu* L. is attacked by several insect and non–insect pests. They infest all parts of the palm such as roots, stem, leaves, inflorescence and nuts. Since the earliest record of brown bug *Saissetia hemisphaericum* Targ. as a pest of arecanut by Coleman and Rao (1918), about 90 insect and non–insect pests have so far been reported on arecanut palm, including pests on stored arecanut (Appendices 6.1 and 6.2).

Among these, the four pests which cause considerable economic loss to the crop are mites, spindle bug, inflorescence caterpillar and root grubs. They are either seasonal or persistent on the crop. Though not highly host specific, they always infest the crop and assume serious proportions.

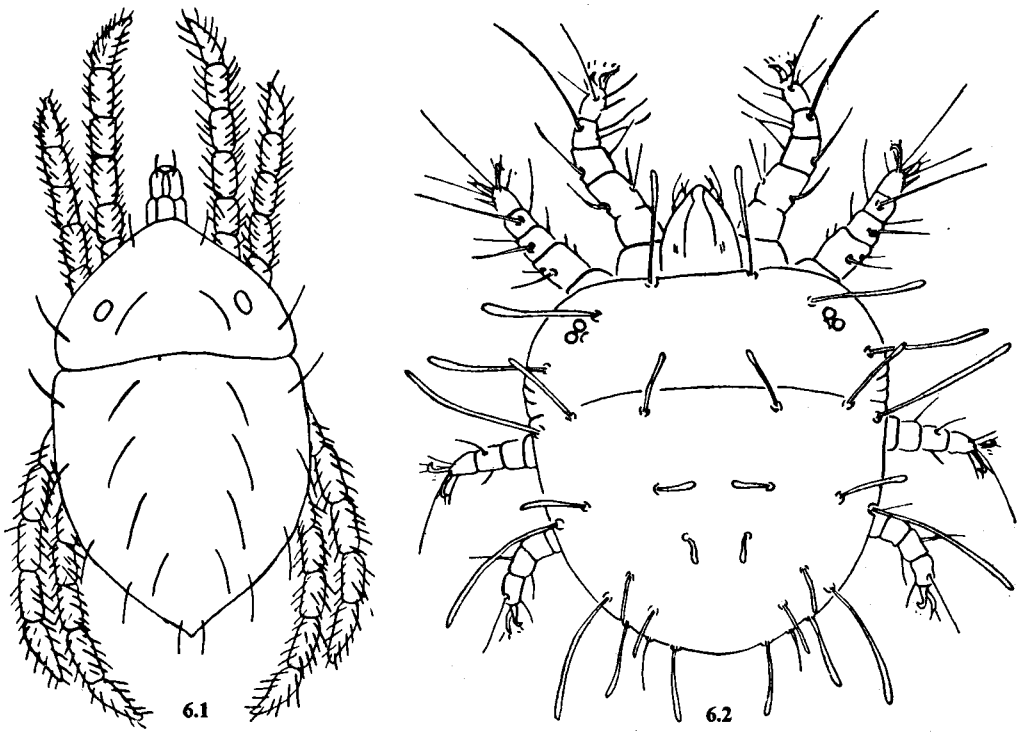
I. Pests causing major crop loss

1. Mites

Two species of leaf feeding mites and one species of perianth mite cause damage to the arecanut palm. The two major species of foliage mites are the cholam mite (*Oligonychus indicus* Hirst), and the palm mite (*Raoiella indica* Hirst).

Oligonychus indicus Hirst (Acarina: Tetranychidae): This is commonly known as white mite. Puttarudriah and Channabasavanna (1956) first reported this spider mite (Fig. 6.1) on arecanut seedlings near Bangalore in Karnataka. Both adults and nymphs colonise under webs on the lower surface of leaves, which is characteristic of the species.

The incubation period varies from 72 to 95 hr. The larval, proto–nymphal and deuto–nymphal periods last 26.6, 30.8, and 44.0 hr respectively. The total duration of the immature stages varies from 6.5 to 9.0 days with an average of 7.5 days. The female mite lays on an average 3–4 eggs per day and the average oviposition period lasts 10.1 days (Anonymous, 1970).



Figs. 6.1—6.2 Arecanut mites. *Fig. 6.1 White mite; Fig. 6.2 Red mite.*

Raoiella indica Hirst *(Acarina: Tenuipalpidae):* The palm mite *R. indica* (Fig. 6.2) commonly known as red mite is active during summer months. Both the adults and nymphs are seen in large numbers on the lower surface of arecanut leaves, though in severe cases of infestation they are seen on the upper surface, leaf stalks and on the spindle. Puttarudriah and Channabasavanna (1956) first recorded *R. indica* on arecanut seedlings at Hebbal, Bangalore.

The life cycle of the female and male mites is completed in 12.9 days and 11.2 days respectively, during April–May (Anonymous, 1977).

R. indica is also observed on coconut, date palms, *Areca macrocalyx* and the ornamental palm, *Livistona chinensis.*

i. *Seasonal abundance of arecanut mites*

The mite population starts building up soon after the monsoon. With the onset of hot weather they become more active and attain virulent form

especially during the summer months in April–May (Patel and Rao, 1958). Poorly irrigated gardens and nurseries particularly those in exposed situations are very much prone to mite infestation. The pest incidence is less under well–irrigated and partially shaded conditions. The mite population declines with the onset of monsoon.

ii. *Symptoms of infestation*

Very often colonies of *O. indicus* and *R. indica* coexist on the same leaf. They suck the sap from the green portion of the plant. Due to their feeding, yellowish speckles develop on the lamina. These speckles later coalesce, become bronze coloured (Fig. 6.3) and the leaves wither away. The growth of the fungi *Meliola* sp. and *Capnodium* sp. on the leaves associated with mite infestation interfere with the normal photosynthesis of the affected leaves (Menon, 1960). In the case of infestation all the leaves in the seedlings are affected causing often death of the seedling. In older palms infestation starts in the lower whorl of leaves and as the population increases it spreads to the inner whorl.

iii. *Control*

Heavily infested and dried leaves are to be cut and burnt to check the spread of mites. Bhat, Patel and Bavappa (1957) suggested spraying with wettable sulphur, Folidol or dusting with lime and sulphur at 2:1 ratio for control of mites. Puttarudriah and Channabasavanna (1957b) suggested soil application of Systox, Solbar and Pestox 3H besides wettable sulphur for the control of areca mites. Patel and Rao (1958) reported that spraying of Folidol E 605, Systox or Ekatin was effective in control of foliage mites. Ponnuswamy (1966) suggested spraying of 0.03% Parathion or Malathion and 2% Parathion dust and sulphur dust for control of *R. indica* on arecanut.

O. indicus and *R. indica* can be controlled by spraying with dicofol (Kelthane 1.86 ml/litre of water), carbophenothion (Trithion 1.26 ml/litre of water) or chlorobenzilate (Akar 338 one ml/litre of water) (Anonymous, 1967). Maximum ovicidal effect on *O. indicus* was shown by Kelthane (1.86 ml/litre of water) (Anonymous, 1969a, 1969b). Kantha, Ray and Lal (1963) reported ovicidal action of Kelthane resulting in 23% reduction in hatching of eggs at 0.1% concentration.

Puttarudriah and Channabasavanna (1956) reported many coleopterous predators chiefly coccinellids of the palm mites. They include *Aspectes indicus* Arrow (Dermestidae), *Cybocephalus semipictis* Champ–var (Nitidulidae), *Stethorus*

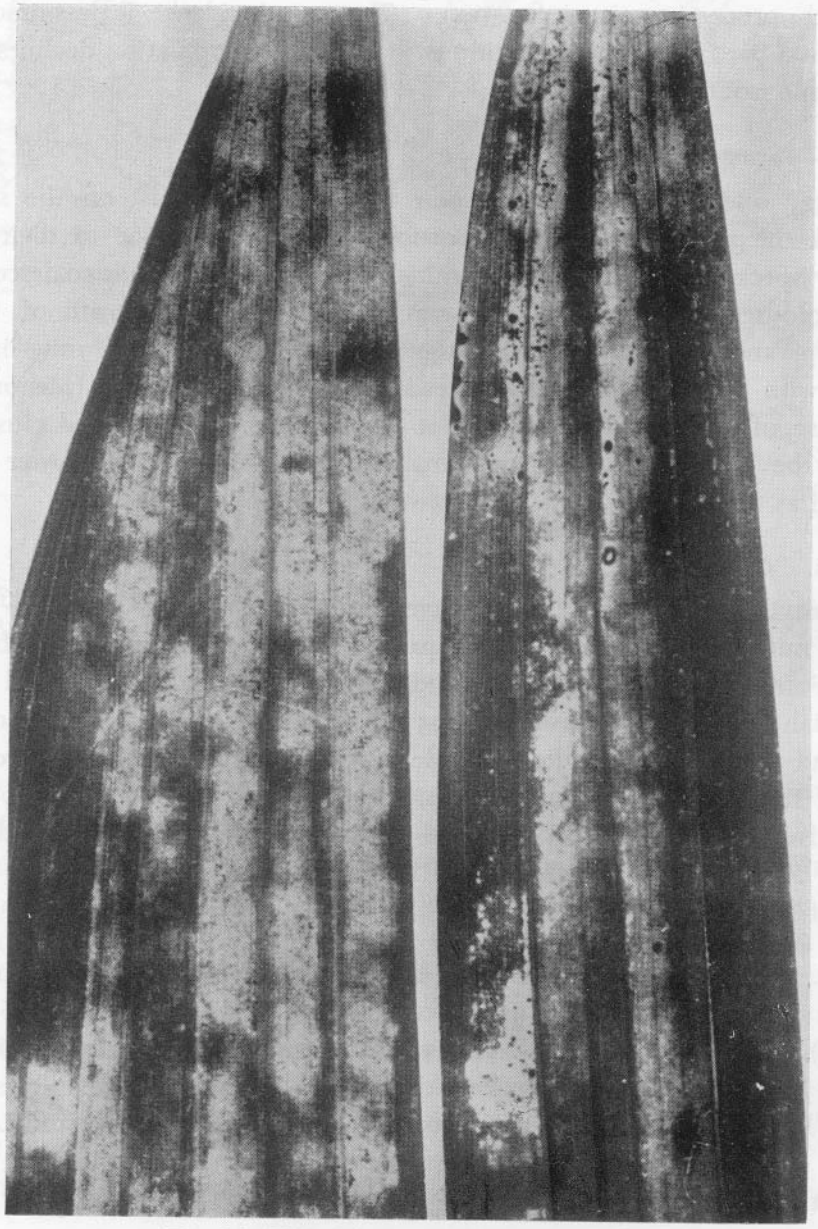


Fig. 6.3 Mite infestation on areca leaflets

parcepunctatus Kapur, *S. tetranychi* Kapur, *Juaravia soror,* (Wse.) and *Spilocaria bisselata* Muls. (Coccinellidae). These predators particularly the species of *Stethorus* keep the mite population in check during summer months. *Stethorus keralicus* Kapur (Coccinellidae) as a predator on *R. indica* was recorded by Kapur (1961). This ladybird beetle is one of the major predators of the mite and takes 12–14 days to complete its life cycle (Daniel, 1976).

Daniel (1979) recorded a number of indigenous predators and among them two species of *Stethorus* and a staphylinid beetle are the major predators of *O. indicus.* The coccinellid *S. keralicus* and the phytoseiid *Amblyseius channabasavanni* Gupta and Daniel are the key predators of the palm mite *R. indica.* Details of other members of the predator complex of *R. indica, O. indicus* and *Tetranychus fijiensis* Hirst are furnished in Table 6.1.

Table 6.1. *Natural enemy complex of arecanut phytophagous mites*

Coleoptera	:	Coccinellidae	– *Stethorus keralicus* Kapur on *Raoiella indica* H. *Stethorus* spp. on *Oligonychus indicus* H. and *Tetranychus fijiensis* H.
	:	Staphylinidae	– A single species on *O. indicus* and *T. fijiensis.*
Thysanoptera	:	Thripidae	– A single species on *O. indicus.*
Neuroptera	:	Chrysopidae	– *Chrysopa* sp. on *R. indica* and *O. indicus.*
Hemiptera	:	Anthocoridae	– A single species on *R. indica.*
Diptera	:	Cecidomyiidae	– A species related to the genus *Arthrocnodax* on *R. indica* A species related to the genus *Feltiella* on *R. indica* A species on *O. indicus* and *T. fijiensis.*
Acari	:	Phytoseiidae	– *Amblyseius channabasavanni* on *R. indica and T. fijiensis.* *Typhlodromus* sp. on *O. indicus.*
	:	Araneida	– A single species on *R. indica.*

The females of predacious mite *A. channabasavanni* require an average of 98 hr and males an average of 93.3 hr to complete the developmental period on the eggs of *R. indica.* A total of 15–38 host eggs are consumed during this period by female and 14–19 eggs by males (Daniel, 1981).

Attempts to introduce the predacious mite *Phytoseiulus persimilis* A–H for the control of *O. indicus* and *R. indica* were not successful as the predator could not acclimatise itself to the local conditions at Vittal in Dakshina Kannada district of Karnataka (Daniel and Seshadri, 1976).

2. Spindle bug *Carvalhoia arecae* Miller and China (Heteroptera: Miridae)

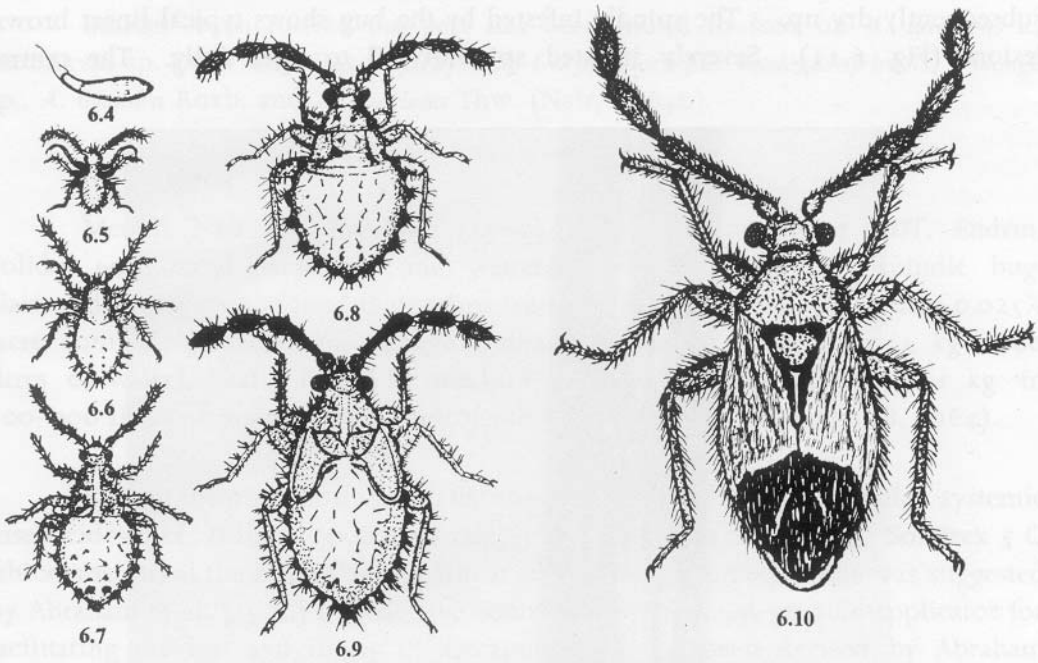
This capsid (=Mirid) bug was first reported as a pest of arecanut palm from Dakshina Kannada, Karnataka by Khandige (1955). Miller and China (1957) described it as *Carvalhoia arecae* based on the specimens collected from Dakshina Kannada. Detailed biology of the pest was studied by Nair and Das (1962). The bugs are seen in colonies within the top most leaf axil of the arecanut palm. More than 80 per cent damage to the spindle has been observed in certain gardens in South Kerala and parts of Dakshina Kannada in the case of severe infestation (Nair, 1964a; Abraham, 1976).

Twenty four to thirty three days are required for the bug to complete life cycle (Nair and Das, 1962). The egg is oval measuring 1.36 mm × 0.34 mm (Fig. 6.4). The anterior end is distinctly demarcated into a short neck bearing at its tip an oval convex operculum. The chorion is smooth and leathery and the operculum is thick and rigid. Two bristle like chorionic processes arise from the operculum. One of them is very long and the other is short and slightly curved. Freshly laid egg is milky white. Gradually the egg turns to pink and then red on further development. It hatches out in 9 days. The eggs are thrust singly into the tissues of tender unopened leaves. The site of egg laying becomes dark in colour. Rarely two or three eggs are laid together.

There are five nymphal instars which extend for 15–24 days (Figs. 6.5—6.9). The newly hatched nymph is 1.07 mm long. The head is triangular with a pair of four jointed antennae. The rostrum is three segmented and reaches up to hind coxae. The thoracic segments are equal in size. The legs are long, six segmented and each bears a two segmented tarsus. The abdomen is oval with nine visible segments. The antennae, legs and rostrum are deep violet brown; thorax and border of abdomen light violet brown, remaining part of abdomen greenish yellow and the head light yellow with scarlet red eyes. The wing rudiments appear towards the end of this instar. The fifth instar nymph is 4.43 mm long and 2.15 mm broad. Wing pads are well developed reaching upto the third abdominal segment in the fifth instar nymph.

The adult bugs are 6.0 mm long and 2.8 mm broad (Fig. 6.10) and red and black in colour. The females are slightly bigger than the males. The abdomen of the female bug is broader and stouter. Sexes can be easily distinguished by the black colour of the abdominal tip on the ventral side.

In the male, this colour is confined to the lateral border of the sixth, seventh and whole of the eighth abdominal segments. In females the black colouration extends medially upto the fourth abdominal segment.



Figs. 6.4—6.10 Life cycle of spindle bug. *Fig. 6.4 Egg; Figs. 6.5—6.9 Nymphs; Fig. 6.10 Adult.*

i. *Seasonal abundance*

According to Nair (1964a), the peak incidence of the pest in Kerala is from June to October with maximum population in August and September. But a high population density in December–January and July has also been reported (Anonymous, 1972). According to Koya et al. (1979) the pest population is high during the monsoon and post–monsoon periods and low during summer months.

ii. *Nature of feeding and symptoms of infestation*

Both the nymphs and adults suck the sap from the tender spindle and leaves. While feeding the stylet is thrust into the tissues by bending the rostrum slightly and feeding is completed in about 20 minutes. Immediately after the feeding a longitudinal, narrow discoloured zone is formed on the sides of the feeding point. According to Nair and Das (1962) it appears that the bug injects probably saliva

with some digestive enzymes into the tissues, which liquefies the cell contents before feeding. The liquefied cell content is sucked by the bug.

The infested portions develop necrotic patches which turn brown and subsequently dry up. The spindle infested by the bug shows typical linear brown lesions (Fig. 6.11). Severely infested spindles fail to open fully. The central

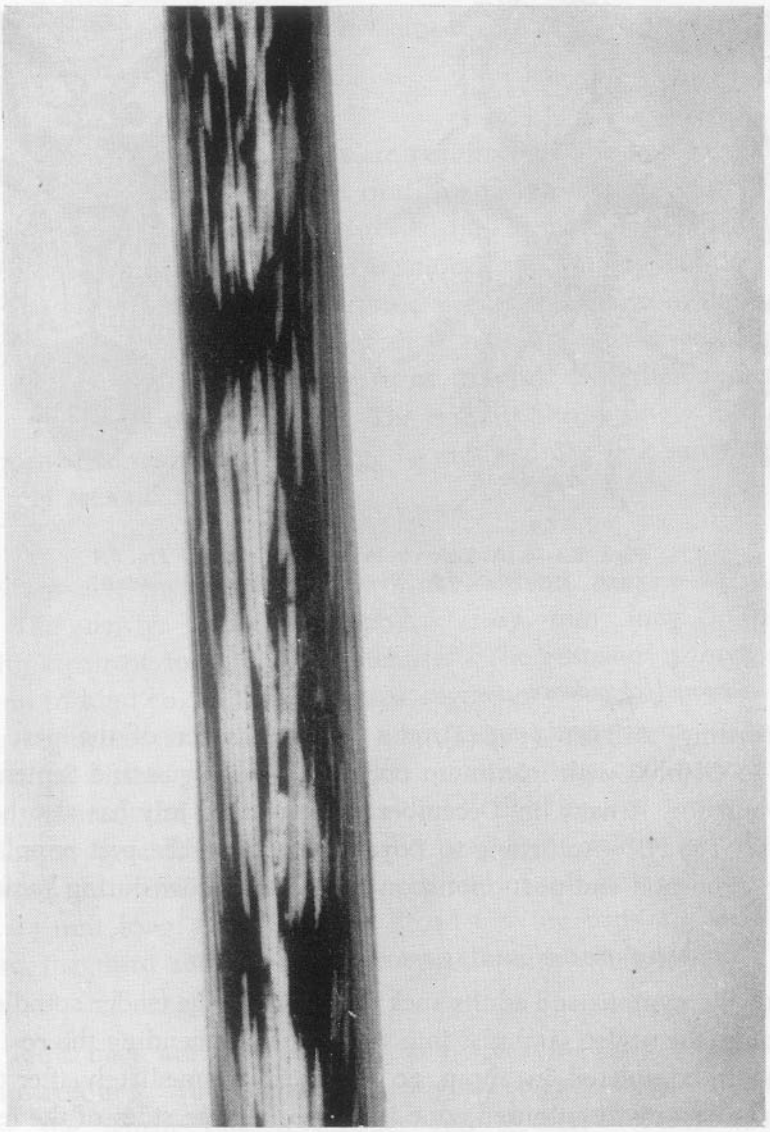


Fig. 6.11 Lesions on the spindle caused by the bug

portions of the necrotic patches after turning brown often drop off forming numerous holes on the leaves. Due to severe infestation the leaves are shredded and the palms become stunted.

Besides *Areca catechu* the pest has been found to feed on *A. lutescens* L., *Loxococcus* sp. (Nair and Das, 1962) and *Chrysalidocarpus madagascariensis, Pinanga* sp., *A. triandra* Roxb. and *A. concinna* Thw. (Nair, 1964b).

iii. *Control*

Menon, Nair and Abraham (1962) suggested spraying of DDT, Endrin, Folidol 605 (ethyl parathion) and wettable BHC to control the spindle bug. Nair and Das (1962) found that palms treated with BHC 0.2% and Endrin 0.025% were completely free from damage. Spraying fish oil resin soap (1 kg in 80 litres of water), Ekatin (1 ml in one litre of water) or Endrin (Endrex) (1 kg in 700–900 litres of water) could control the pest effectively (Anonymous, 1964).

Filling the innermost leaf axils around the spindle with granular systemic insecticides like Thimet 10 G (phorate) or Sevin 4 G (carbaryl) or Solvirex 5 G (thiodemeton) at the rate of 10 g/palm at an interval of three months was suggested by Abraham et al. (1976) for effective control of the pest. A granule applicator for facilitating the leaf axil filling of arecanut palm has been devised by Abraham (1975). Koya et al. (1979) in a field trial with granular insecticides at Palode (South Kerala) found that all the insecticides were effective in giving significant control of the pest, and the palms treated with quinalphos (Ekalux) granules showed lower population of the bug and minimum leaf damage (Table 6.2 and 6.3).

Table 6.2. *Population count of spindle bug on palms under different treatments*

Treatments	Mean number of spindle bug/palm
Lindane 6G	8.4
Carbaryl+Lindane 4:4G	8.3
Carbaryl 4G	10.6
Mephosfolan 5G	12.0
Thiodemeton 5G	11.5
Quinalphos 5G	6.9
Control (untreated)	18.6
SE/Mean = 1.28	CD = 3.95

Table 6.3. *Percentage leaf attack by spindle bug under different treatments*

Treatments	Percentage leaf attack				
	Pre-treatment	Post-treatment (intervals of 6 months)			
		1	2	3	4
Lindane 6G	81.4	31.9	47.2	30.6	24.7
Carbaryl+Lindane 4:4G	75.5	28.2	48.8	24.6	21.2
Carbaryl 4G	80.2	38.8	47.9	31.1	25.6
Mephosfolan 5G	96.4	40.5	44.9	32.4	27.4
Thiodemeton 5G	75.0	33.8	39.4	21.7	23.6
Quinalphos 5G	78.1	34.5	39.6	19.6	13.3
Control (untreated)	66.0	58.2	78.3	43.1	50.2

3. Inflorescence caterpillar *Tirathaba mundella* Walker (Lepidoptera: Pyralidae)

This lepidopteran caterpillar causes damage to areca inflorescence in pockets of Dakshina Kannada district in Karnataka and Trichur district in Kerala (Anonymous, 1962; Nair and Rawther, 1969).

i. *Biology and nature of damage*

The female moth deposits egg into the spadix through punctures made on the spathe by slugs or snails (Fig. 6.12). The eggs are also deposited on the under surface of the spathe. The egg period lasts for 5 days. The full grown larvae is greyish brown with a reddish brown head and measures 23–25 mm in length. The larval period lasts for about 26 days covering five instars. Pupation is in silken cocoons with a wet mass of frass inside the spathe. Pupal period lasts 9–11 days (Figs. 6.13—6.16) (Nair and Rawther, 1969).

The caterpillars that emerge out bore into the interior of the spathe. They move towards the tip of the inflorescence and commence feeding on the tender rachillae and male flowers (Fig. 6.17). In severe cases, the caterpillars may bore into the tender buttons as well. They are very sensitive to light and web together the terminal portions of the inflorescences with silken threads and throw out large wet masses of frass. As a result of the webbing, the inflorescence fails to exert the natural pressure on the spathe and eventually the opening of the spathe is delayed (Nair and Rawther, 1969).

ii. *Control*

Spadices showing external indication of damage by slugs or traces of frass and oozing out of brownish sap or fluid may be force–opened and if all the female flowers have been damaged, the inflorescence should be removed and burnt. If the

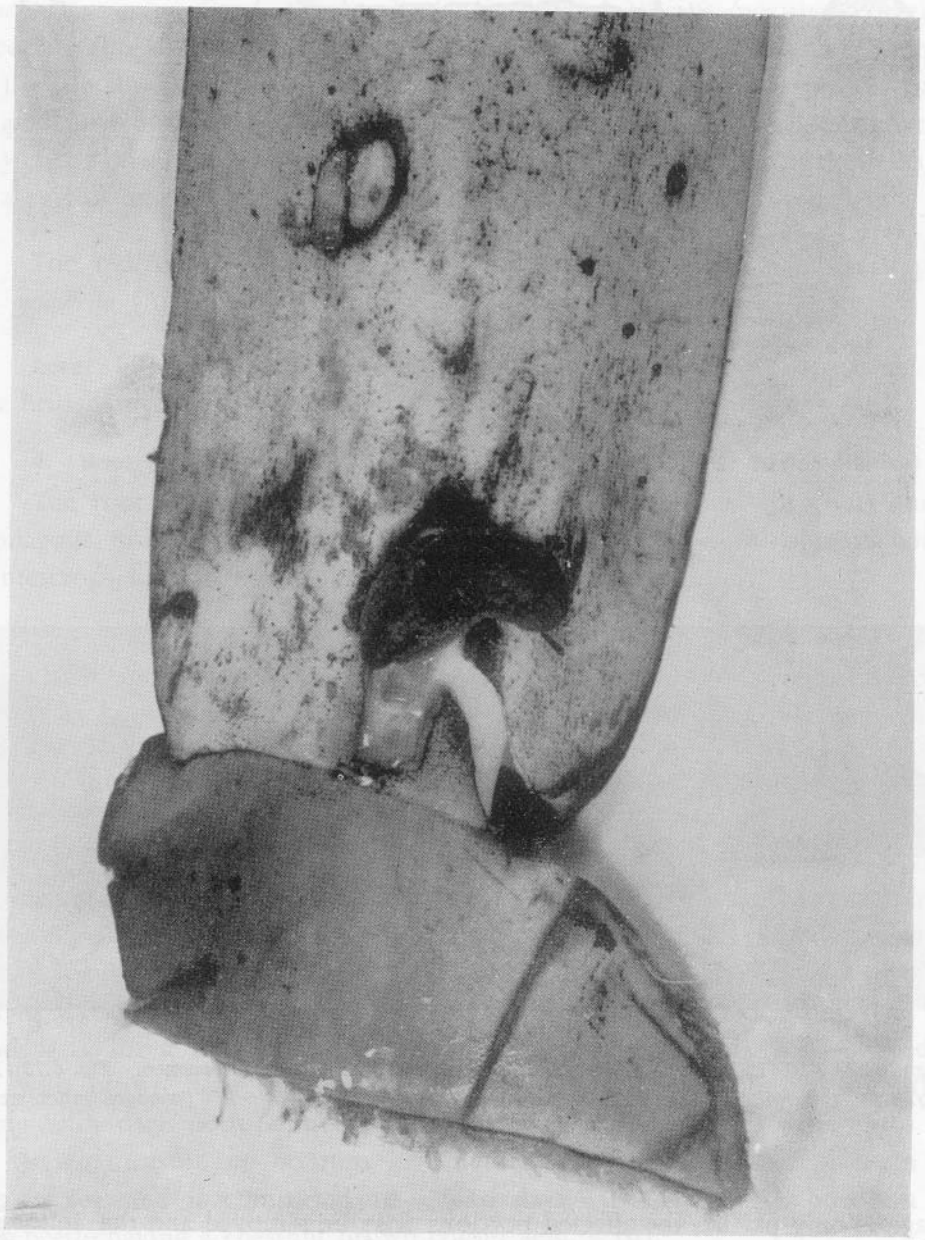
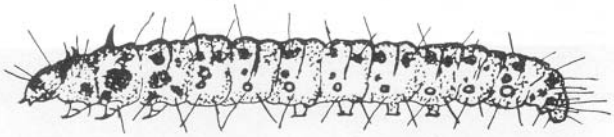


Fig. 6.12 Slug damage on spathe

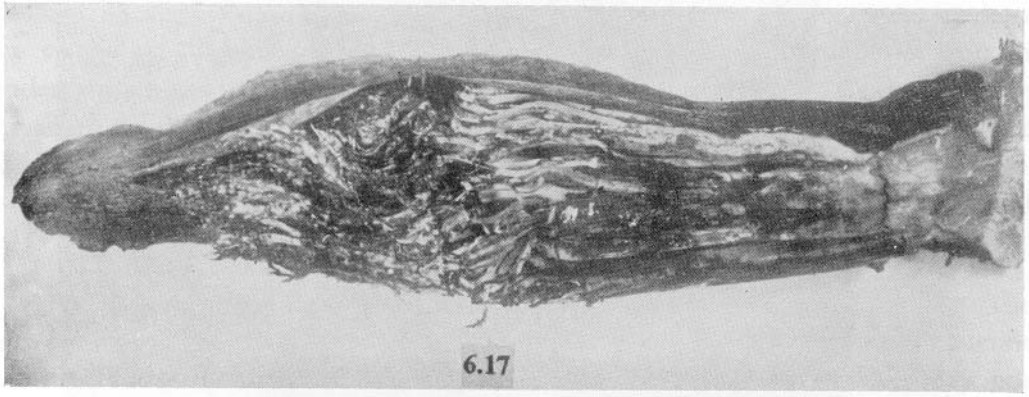
6.13



6.14

6.15

6.16



6.17

Figs. 6.13—6.16 Life cycle of *T. mundella* and the damaged inflorescence. *Fig. 6.13 Egg; Fig. 6.14 Caterpillar; Fig. 6.15 Pupa; Fig. 6.16 Adult; Fig. 6.17 Damaged inflorescence.*

damage is only partial, the affected portions may be removed and the inflorescence sprayed with 0.125% Endrex 20 EC (Anonymous, 1962) or 0.125% Malathion (Anonymous, 1971a). Since it is the injury by slugs that predisposes the unopened inflorescences to the infestation of inflorescence caterpillar, control measures are to be taken against the slugs.

The slug causing damage to the arecanut inflorescence has been identified as *Mariaella dussumieri* Gray. There was a highly significant positive correlation between the slug damage and the caterpillar incidence on areca spathes (Anonymous, 1981). The slugs could be controlled by either hand picking or poison baiting with a mixture of bran, molasses or jaggery, lead arsenate and water (Anonymous, 1962). The poison bait containing a mixture of bran and cement in the ratio 13:2 with a part of metaldehyde has also been suggested (Anonymous, 1971b).

The red ant *Monomorium gracillimum* Sm. feeds on the young caterpillars of *T. mundella* (Anonymous, 1962).

Lever (1937) noted the occurrence of *T. rufivena* Walk. on areca palm in the British Solomon Islands.

4. Root grub *Leucopholis burmeisteri* Brenske (Coleoptera: Melolonthidae)

The root grubs or white grubs are voracious feeders on roots and are polyphagous in nature. Besides the arecanut palm, they feed on roots of coconut and intercrops such as banana, yams and other tuber crops.

The root grubs affecting arecanut are *Leucopholis lepidophora* Blanch (Puttarudriah and Channabasavanna, 1956), *Lepidiota* sp. (Rao, Naidu and Bavappa 1961) and *Leucopholis burmeisteri* Brenske (Anonymous, 1967). *L. burmeisteri* is the most common species infesting arecanut in Dakshina Kannada district.

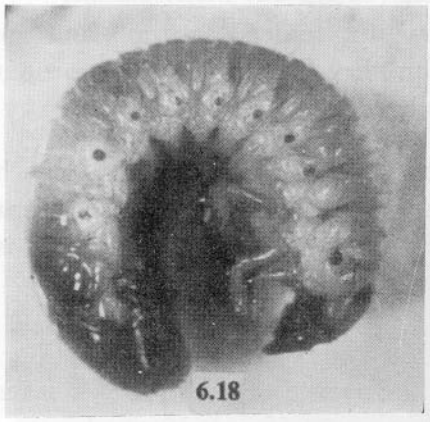
i. *Biology*

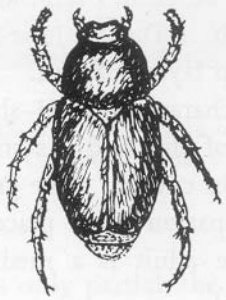
L. burmeisteri has an annual life cycle. Emergence of adult beetles takes place during the premonsoon showers in May–June. The female beetles lay eggs in the loose soil around the root zones. The eggs are smooth, round and creamy white. Incubation period lasts for more than a month. During June–July large number of early instar grubs can be seen on the top layers of soil. The larval period lasts for a few months. The larvae have a characteristic U-shaped soft body with brown head (Fig. 6.18). The hind part of the body is smooth and shining with dark body contents seen through the thin cuticle. The grubs when fully grown measure 50–60 mm in length. The pupation takes place in deep layers of soil and is completed in 35–40 days. The adult is a medium sized chafer beetle having a chestnut brown colour (Fig. 6.19).

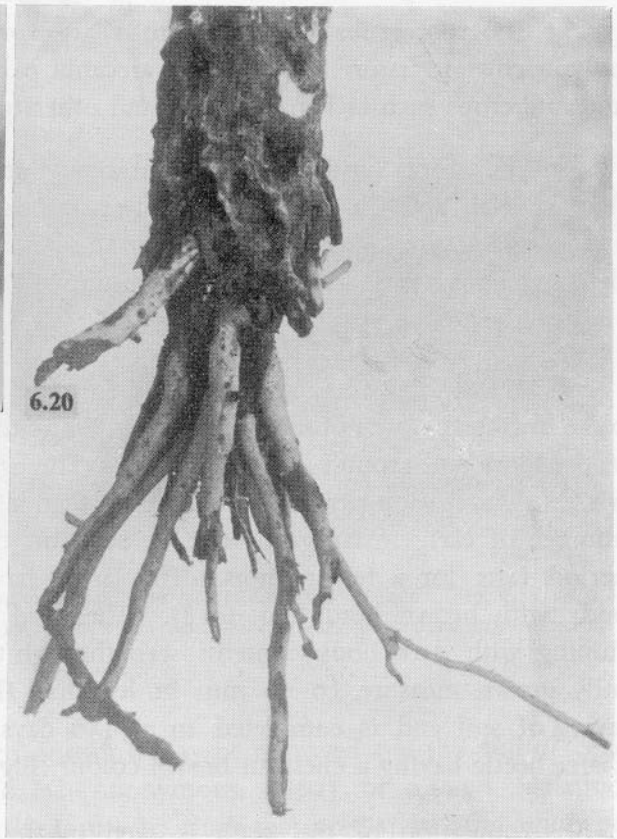
Population of the grub is seen in the moist soil from May–June till February–March. As many as 40–50 grubs could be dug out from the base of severely infested palms (Rao et al., 1961). The presence of the grubs in the deep

layers of the soil is highly related to the water table of the garden. In infested gardens with higher water table the grubs will be seen in top layers of soil. The incidence of the pest is more in ill-drained and low-lying clayey soils.

The root grubs feed on the roots, particularly tender ones. The roots are damaged near the bole either by eating the tender roots from the tip or cutting them across at various points (Fig. 6.20). In rare cases of severe infestation the grubs feed on the entire bole region. When all the roots are destroyed the palm will lose its grip on the soil and it will be toppled down. In the *Maidan* areas of Karnataka, the white grubs were reported to be serious on nursery seedlings and young palms (Rao et al., 1961).







Figs. 6.18—6.19 Grub and adult of *L. burmeisteri*.
Fig. 6.20 Damaged bole and roots.

The visual symptoms of infestation in the nursery are the drooping and complete drying of the leaves within two to three days. The affected seedlings can be pulled out easily as they have an entirely damaged root system. Mortality is quicker in younger palms. Older palms will continue to survive for a longer period. Due to feeding of roots the leaves turn to a sickly pale yellow. Tapering of the stem, reduced yield, nut fall and production of less number of bunches are the other symptoms of white grub infestation.

ii. *Control*

Soil insecticides control white grubs effectively. Chlordane and Heptachlor were earlier recommended for the control of white grubs on arecanut (Anonymous, 1961; Rao et al., 1961). In an insecticidal trial, Intox-'8' liquid (Chlordane) applied at the rate of 50 ml in 100 litres of water around the root zone was quite effective in controlling arecanut white grubs. (Rao et al., 1961). Application of Heptachlor 20 EC at 6.3 ml per 100 litre water, BHC 5% dust at 63.08 kg per ha and Chlordane 5% dust at 31-54 kg per ha (Rao, 1963), Thimet 10 G (phorate) at the rate of 8g per palm applied at the base (Anonymous, 1972) Rogor 5 G (dimethoate) granules at the rate of 30 kg per ha (Kumar, 1974) gave good control of white grubs.

Results of field trials using systemic granules, soil amendments and contact insecticides showed that Rogor 5 G (dimethoate) at 30 kg per ha (Table 6.4), *Pongamia* oil cake at 2000 kg per ha (Table 6.5), Chlordane 5% dust at 90 and 120 kg per ha, BHC5% dust at 120 kg per ha and Ekalux (quinalphos) 1.5% dust at 90 and 120 kg per ha (Table 6.6) applied twice in an year in May and November for three years were effective in giving significant control of the grubs (Kumar and Daniel, 1981).

Table 6.4. *Mean grub counts per plot treated with different insecticides*

Insecticide and dosage (kg/ha)	Mean grub count during different years			
	1972-'73	1973-'74	1974-'75	Mean
Phorate (Thimet 10G @ 15 kg)	4.18	3.95	2.54	3.55
Thiodemeton (Solvirex 5G @ 30 kg)	4.56	4.19	2.98	3.91
Thiodemeton (Disyston 5G @ 30 kg)	4.61	3.78	2.36	3.58
Dimethoate (Rogor 5G @ 30 kg)	3.23	3.26	2.10	2.86
Carbofuran (Furadan 3G @ 45 kg)	4.69	4.14	2.75	3.86
Chlordane (dust 10% @ 30 kg)	4.94	3.69	2.44	3.71
Control (no treatment)	8.39	6.16	5.09	6.55

Table 6.5. *Mean grub counts per plot treated with different oil cakes*

Oil cakes and dosage (kg/ha)	Mean grub count during different years			
	1973–'74	1974–'75	1975–'76	Mean
Neem cake 1000 kg	4.19	4.03	3.67	3.99
Neem cake 2000 kg	4.66	3.66	3.64	3.99
Pongamia cake 1000 kg	3.87	3.87	3.85	3.86
Pongamia cake 2000 kg	3.69	2.03	2.91	3.14
Control (no treatment)	4.36	4.82	4.55	4.57
C.D. P = 0.05	0.72	0.76	0.84	0.34

Table 6.6. *Mean grub counts per plot treated with different insecticide dusts*

Insecticide and dosage (kg/ha)	Mean grub count during different years			
	1973–'74	1974–'75	1975–'76	Mean
BHC 5% 60 kg	5.67	5.32	2.69	4.56
90 kg	4.54	4.99	2.46	3.99
120 kg	4.31	3.98	1.98	3.43
Chlordane 5% 60 kg	4.84	4.93	2.36	4.04
90 kg	4.19	3.88	1.74	3.27
120 kg	4.11	3.10	1.41	2.87
Heptachlor 60 kg	5.31	5.47	2.93	4.57
90 kg	4.53	4.64	2.44	3.87
120 kg	4.43	3.66	2.30	3.85
Aldrin 5% 60 kg	5.52	4.72	2 44	4.22
90 kg	5.09	4.55	2.61	4.08
120 kg	5.06	3.87	2.20	3.74
Quinalphos 1.5% 60 kg	5.14	5.06	2.64	4.28
90 kg	4.79	4.35	2.06	3.73
120 kg	3.22	4.08	2.14	3.14
Control (no treatment)	7.74	6.30	4.24	6.09
C.D. P = 0.05	0.67	0.61	0.84	0.39

The nematode cum bacterium culture DD–136 *Neoaplectana carpocapsae* Weiser and *Achromobacter nematophilus* (Poinar and Thomas) has been tested for the biological control of this pest. A suspension of 60–100 nemas killed the early instar grubs in five days. Soil treatment with 600–800 nemas killed the grubs in 23 days (Anonymous, 1974).

II. Minor pests

1. Nursery pests

Daniel and Kumar (1976) in their review on the pests of arecanut reported six species of insects associated with arecanut in nurseries. Seedlings in the primary nursery as well as secondary nursery and also the transplanted seedlings in the main field are subject to damage by many insects other than the major pests of the crop. Description of some of the more important pests of seedlings are furnished here.

i. *Bagworms (Lepidoptera: Psychidae)*

Pillai and Kurian (1959 b) reported *Manatha albipes* Moore on arecanut. Other two species *viz., Cryptothelia* sp. and *Thyridopteryx* sp. have also been reported from Kerala (Nair and Menon, 1963). These are found in large numbers feeding on the lower side of leaves. The attacked leaves show numerous small holes. Bagworms can be controlled by spraying 0.2% BHC.

ii. *Termites* Odontotermes obesus *Ramb (Isoptera: Termitidae)*

Termites infest seednuts and seedlings in nursery during dry weather (Pillai and Kurian, 1959 b; Rao et al., 1961; Nair 1975). Rarely they infest the bark of older palms. Normally termites infest seedlings through the collar region. The wilting of central shoot followed by the death of the seedling is the symptom of termite infestation.

Incorporation of soil insecticides like BHC, Aldrin or Chlordane to the nursery soils before sowing of nuts and removal of decaying organic debris from the soil are some of the preventive measures. Covering the nuts with a layer of river sand is also recommended for avoiding termite infestation (Pillai and Kurian, 1959b).

iii. *Grasshoppers (Orthoptera: Acridiidae)*

Two species of grasshoppers *viz., Aularches miliaris* Linn. and *Melanoplus* sp. have been reported to cause leaf damage to arecanut seedlings (Nair and Menon, 1963; Nair 1975). They eat away portions of the lamina causing holes of different sizes. *A. miliaris* was first reported in arecanut by Jones (1954). An epidemic outbreak of *A. miliaris* in June 1975 in Malappuram district, Kerala was reported on teak, coconut, arecanut, coffee, *Erythrina* etc. (Pillai, Dubey and Singh, 1976).

iv. *Nymphalid caterpillar* Elymnias caudata Butl. *(Lepidoptera: Nymphalidae)*

The caterpillars while feeding the leaves clip off the lamina and reduce the leaf area considerably. The pest incidence is more during the period from September to December. The spherical and white coloured eggs are laid on the lower leaf surface. Incubation period lasts for 5–7 days. The caterpillars are pale yellowish in the early instars and when fully grown they are green in colour. Full grown caterpillar measures about 35 mm. The larval period takes about 21–25 days. Pupa is green in colour with yellow and red markings on the body and is about 25 mm long. Pupal period lasts 8–9 days. The adult butterfly is brown with patches of white, yellow and violet colouration (Nair, 1964b). The larvae are parasitized by *Brachymeria* sp (Nair, 1975).

v. *Coccids*

Rao and Bavappa (1961) reported the mealy bug *Dysmicoccus brevipes* Ckll. (Homoptera: Pseudococcidae) and the scale insect *Aonidiella orientalis* Newst. on arecanut seedlings. These insects infest the lamina and collar regions of the seedlings, causing yellowish patches. Treatment with contact insecticides like Malathion or Parathion for their control has been suggested (Rao and Bavappa, 1961).

In addition to the above two species of coccids, Nair (1975) reported the hard scale *Aspidiotus destructor* Sign., *A. ficus* Ash., *Chionaspis dilatata* Gr., *Phenacaspis cockerelli* Cooley, *Pinnaspis buzi* Bouche, *P. dracoenae* Cooley, *Lepidosaphes* sp., *Parlatoria mytilaspiformis* Gr. and *Quadraspidiotus* sp. on arecanut seedlings.

2. Stem feeders

i. *Stem weevil* Diocalandra stigmaticollis *Gyll. (Coleoptera: Curculionidae)*

This weevil was reported from certain areas of Kerala and Mettupalayam in Tamil Nadu (Pillai and Kurian, 1959b; Anonymous, 1963; Naidu and Kumar, 1963). It infests tender portions of the stem covered by the leaf sheath. When the leaves drop off, the damage can be noticed on or above the nodes. The feeding of grubs produces characteristic dents on the stem. The damage can be seen on the successive internodes. As the development of leaves is adversely affected, quite often the leaves fail to develop further and the stem gets weakened and breaks off easily.

The adult weevil is cylindrical and brown in colour with a prominent curved snout. The weevils gain entry through the tender leaf sheaths and lay eggs on the stem surface. The grubs are initially dull white with a brownish head and later turn to creamy white. Fully grown grubs are 8–9 mm long and 2 mm

wide. The pupa is creamy white earlier and later on turns yellow. Pupal period lasts about 12–14 days. Sun scorched or mechanically injured stem is more prone to infestation. Murthy and Hanumanthappa (1965) recommended spraying or dusting with contact insecticides like DDT or BHC for the control of this weevil. Murthy et al., (1965) recorded *D. frumentii* on the stem of arecanut from Mysore. Nair (1975) reported *D. stigmaticollis* on areca inflorescence in some parts of Kerala.

ii. *Shot-hole borer* Xyleborus perforans *Woll. (Coleoptera: Scolytidae)*

Seshadri (1968) recorded this polyphagous pest on arecanut and coconut from different parts of Dakshina Kannada. After entering through the basal portion of the stem, the pest bores upwards gradually. A large number of circular holes extruding frass can be seen on the stem. If damage is severe the leaves turn yellow and the palm dries up. Maximum damage is seen during October–November. Painting of infested stem with contact insecticides like BHC or Dieldrin check the incidence of the beetle. *X. habercorni* was reported on arecanut by Murthy et al., (1965) from Mysore.

iii. *Redpalm weevil* Rhynchophorus ferrugineus *F. (Coleoptera: Curculionidae)*

The grubs of this weevil tunnel through the soft and exposed portions of the stem and crown. The incidence is more in neglected young palms. Pillai and Kurian (1959b) suggested injection of 1 per cent Pyrocone-E for the control of the pest.

3. Leaf feeders

i. *Grapevine thrips* Rhipiphorothrips cruentatus *Hood (Thysanoptera: Thripidae)*

It is widely distributed in India on a variety of host plants including grapevine, pomegranate, crotons, rose, cashew, etc. Its incidence on arecanut is scattered and negligible. Puttarudriah and Channabasavanna (1956) reported the pest on arecanut in Tharikere and Bangalore, Karnataka and Pillai and Kurian (1959a) recorded it in Ochira in Quilon district, Kerala.

The dark brown adults and pinkish nymphs of the thrips occur in groups on the lower surface of arecanut leaves and suck the sap. Feeding marks are seen as silvery blotches. Attacked portions of leaves turn brownish yellow and dry away(Fig. 6.21). Areca palms of all ages are infested by thrips and often the pest may assume serious proportions during summer in certain localised tracts.

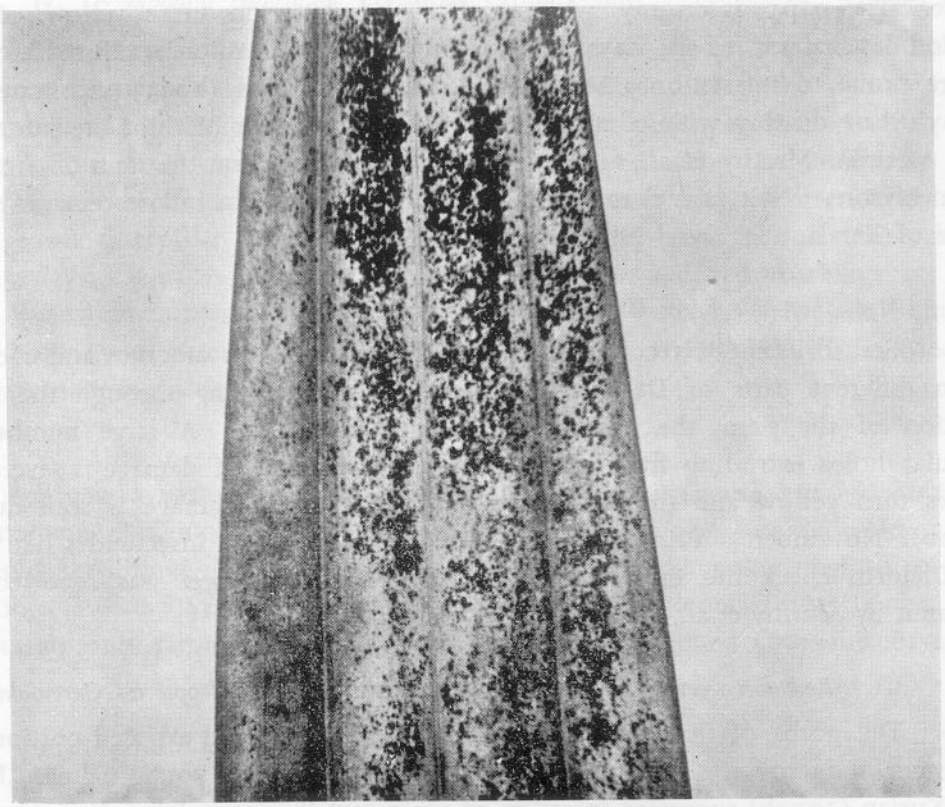


Fig. 6.21 Thrips damage on areca leaflet

Biology of the pest on arecanut was studied by Pillai and Kurian (1959a). The egg period varies from 3 to 8 days. The duration of the immature stages ranges from 11 to 24 days. Total duration of life cycle ranges from 14 to 33 days. The pest could be successfully controlled by spraying Malathion. This pest is attacked by an endoparasite *Thripoctenus maculatus* Waterston (Hymenoptera: Eulophidae).

ii. *Scale insects and mealy bugs*

Many species of scale insects and mealy bugs infest the areca leaves. They colonise on the lower leaf surface and in severe cases even the upper lamina will also be affected. The feeding results in the production of yellow patches on the leaves, which under severe infestation cover the entire leaf area. Nair (1975) gave a list of coccids affecting leaves of arecanut palm. The soft scales *Coccus hesperidum* Linn., *C. acutissimum* Gr. and *Saissetia* sp. also infest leaves.

iii. *Rhinoceros beetle* Oryctes rhinoceros L. *(Coleoptera: Scarabaeidae)*

This black beetle occasionally infests arecanut palms besides its normal host, coconut palm. Nambiar (1949) and Valsala (1958) found this beetle damaging the fronds of arecanut palms in West Bengal. In some cases, the adult beetles bore into the stem upto 60–90 cm below the crown exposing inner fibrous tissues (Kumar, Sannamarappa and Khan 1967).

Other foliage feeders include the spider mite *Tetranychus fijiensis* Hirst (Daniel, 1977), the caseworm larvae (Venugopal and Venugopal, 1961) and hairy caterpillar *Euproctis semisignata* Walk (Nair, 1975).

4. Inflorescence, bunch and tender nut feeders

i. *Mealy bugs*

The mealy bug *Icerya aegyptiaca* Dougl. was noted by Puttarudriah and Channabasavanna (1957a) on arecanut from Karwar in Karnataka. Heavy infestation of bunches was sometimes common in isolated tracts. The stalks and basal parts of fruits in various stages of development were completely covered by the mealy bug population (Fig. 6.22). Infestation during the tender nut stage causes immature nut fall. Natural enemies like the adults and grubs of the coccinellid *Rodolia* sp. and the pteromalid parasite *Pachycrepoides coorgensis* keep the pest under check. Nair (1975) also reported the occurrence of *Pseudococcus citriculus* (Green) and *Rostrococcus iceryoides* (Green) in addition to *I. aegyptiaca* infesting arecanut inflorescence as well as leaves.

ii. *Perianth mite* Dolichotetranychus sp. *(Acarina: Tenuipalpidae)*

Perianth mite infestation results in severe tender nut fall in affected palms. Its infestation has been noticed very extensively in areas around Trichur in Central Kerala. The mite is slender, orange coloured and is seen colonised inside the perianth of tender nuts. As a result of its feeding activity, the nuts shrivel and later on fall off resulting up to 10% crop loss. The period of infestation was during November–May. Sadanandan and Antony (1973) suggested spraying of bunches with dimethoate and formothion at 1 ml and 2 ml per palm respectively.

iii. *Scale insects*

Nair and Menon (1963) and Nair (1975) reported three species of scale insects on arecanut inflorescence *viz., Gossyparia* sp., *Pinnaspis aspidistrae* Sign. and *P. strachani* Cooley. They are rarely seen on leaves too. Adults and nymphs of *Gossyparia* sp. suck the sap from inflorescence. They may sometimes prevent pollination by covering the female flowers. *Pinnaspis aspidistrae* Sign. and

Fig. 6.22 Mealybug *I. aegyptiaca* infested fruit and basal portion of inflorescence

P. strachani Cooley feed on the tender floral parts and cause premature flower and button shedding. Severe infestation results in complete drying of inflorescence.

iv. *Nut borer*

Appanna (1959) mentioned about a lepidopterous borer of tender nuts of areca palm near Koppa, Chickamagalur district, Karnataka. The caterpillar is

dark slate in colour and the attacked nuts show lots of webbed brownish excreta and smaller circular holes on the surface.

v. *Red ants* Oecophylla smaragdina *F. and* Monomorium gracillimum *Sm. (Hymenoptera : Formicidae)*

These ants feed on the honey dew secreted by the coccids and aphids on the inflorescence. They check the proper development of the spathe or the developed spathe do not open completely. With the silken strands, the rachillae are netted together for their harbouring along with coccids. Ultimately the female flowers fall off and the inflorescence dries up. Nair and Menon (1963) reported them to be very serious on arecanut. Sometimes pollination is prevented causing severe button shedding.

5. Vertebrate pests

i. *Squirrels*

Squirrels feed on 3–5 months old tender nuts. The damage is more on arecanut in the *Maidan* tracts of Karnataka causing sometimes as much as 10–15 per cent loss. (Naidu, 1962). Nambiar (1949) reported nearly 20% crop loss in Assam during certain years.

The control measures adopted by the farmers include shooting and setting up bait traps. Spraying of the bunches with 5% solution of zinc phosphide for the control of squirrels has also been recommended (Naidu, 1962).

ii. *Rats*

Rats usually feed on the tender nuts and rarely half mature nuts below the perianth region (Fig. 6.23). Baiting with zinc phosphide and fumigation of burrows are commonly practised for the control of rats. According to Pillai and Kurian (1959b) rats can be successfully controlled by zinc phosphide or anticoagulant rodenticides. The poison is mixed with cereal powder and kept in shallow containers in the crown or base of palm. Trapping, erection of physical barriers and application of chemical repellents etc. are other common remedial measures. Avoiding shelter places in the gardens by clearing bushes would be advantageous in reducing the incidence.

iii. *Other mammalian pests*

The frugivorous bats (fruit eating) or flying fox occasionally cause loss by removing ripe nuts (Pillai and Kurian, 1959b; Daniel and Kumar, 1976). It is rather difficult to control this pest. Breaking their roosts by burning of

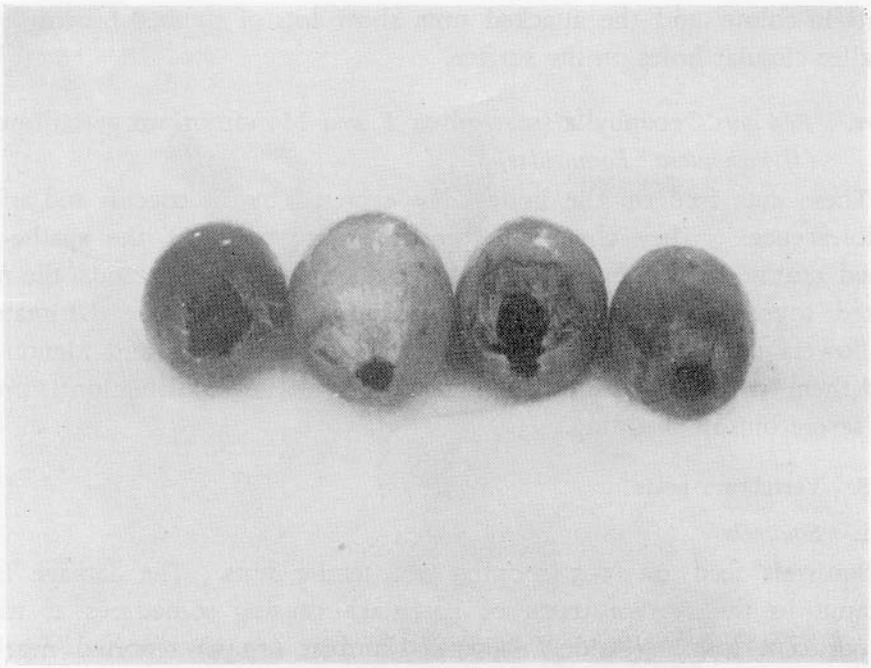


Fig. 6.23 Rat damaged tender arecanuts

sulphur in braziers under the roosting trees may give some temporary relief (Pillai and Kurian, 1959b). Nambiar (1949) reported damage by monkeys in *Malnad* areas of Dakshina Kannada and Uttara Kannada districts of Karnataka and Midnapur district of West Bengal.

Woodpecker is another commonly seen avian pest damaging the arecanut stem in Kerala and Dakshina Kannada (Nair and Menon, 1963). The bird usually pecks the stem tissues weakened by sun-scorching and this hastens the deterioration of the tissues.

III. Storage pests

The husked arecanut known as *chali* is stored in godowns, sometimes even upto one year in gunny bags before marketing. Insect damage becomes a problem under storage conditions. The insects feed on the inner central core and due to their feeding, lot of holes appear on the surface of the nut (Fig. 6.24). Ayyar (1940) was the first to report insect infestation in stored arecanut caused by *Araecerus fasciculatus* D. Later, Nair and Oommen (1969) published the results of a survey

of storage pests of arecanut in Kerala. They listed 14 insects and mites and outlined the biology of the more important storage pests. Daniel and Kumar (1979) recorded 21 species of insect and mites infesting stored arecanuts, in a survey of godowns in Mangalore.

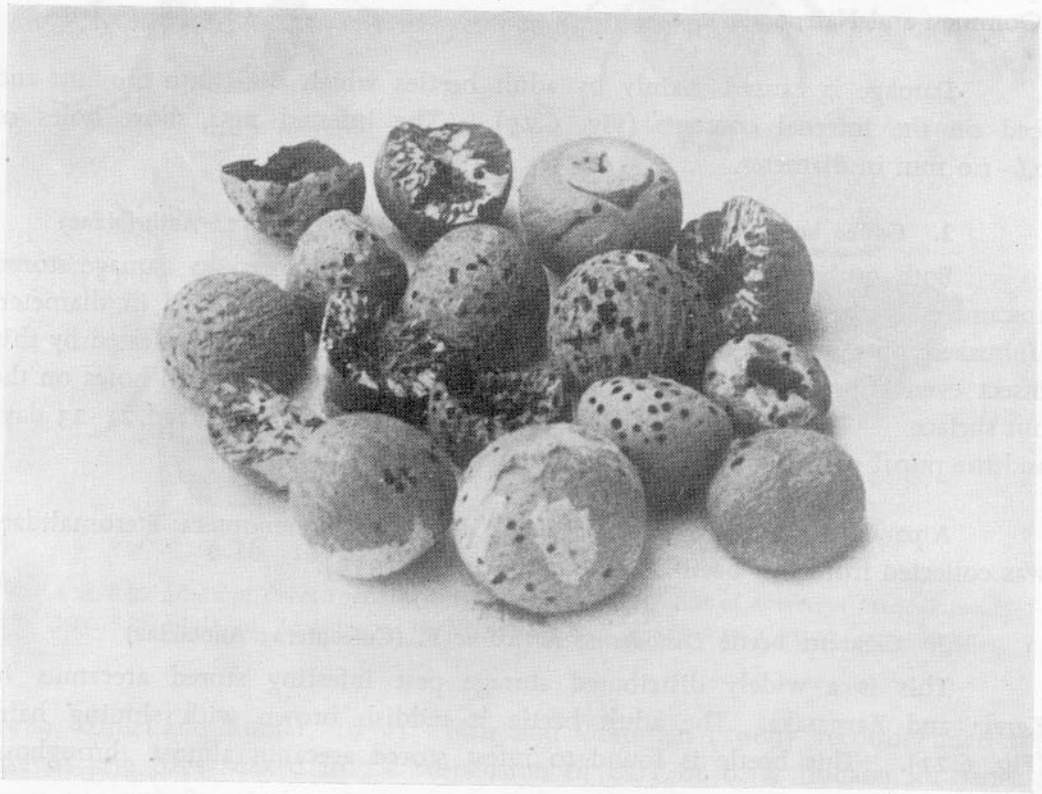


Fig. 6.24 Insect damage on stored arecanut

Tender arecanut chips show maximum resistance to infestation by insects (Nair and Oommen, 1969).

Daniel and Kumar (1979) found that insect damage was maximum during the rainy months when the atmospheric humidity was high and minimum during winter and summer months. The moisture content of the stored arecanuts varied from 8.0% to 28.3% on oven dry weight basis. Details on the life history and nature of damage of the important pests are given here.

1. Arecanut beetle *Coccotrypes carpophagus* Horn (Coleoptera: Scolytidae)

This is the most important storage pest of arecanut. Beeson (1941) furnished a list of host materials of this insect. The damage was maximum during November. Nuts affected by this beetle are not seen to develop secondary infestation by other insects. Damage upto even 100% has been reported in a few cases (Daniel and Kumar, 1979). Its life cycle is complete in 22–29 days (Oommen and Nair, 1968).

Damage is caused mainly by adult beetles which bore into the nuts and feed on the internal contents (Fig. 6.25). The infested nuts show holes of 0.6–1.0 mm in diameter.

2. Coffee bean weevil *Araecerus fasciculatus* D. (Coleoptera: Anthribidae)

Both grubs and adults (Fig. 6.26) have been reported to damage stored arecanut (Ayyar, 1940). Infested nuts show holes 1.5–2.5 mm in diameter. Unhusked nuts with intact perianth were not seen to have been infested by this insect even after one year of storage. Eggs are laid singly in small holes on the nut surface. The incubation period lasts for 5–6 days, larval period 21–23 days and the pupal period 7 days (Nair and Oommen, 1969).

A parasite, *Anisopteromalus calandrae* (Howard) (Hymenoptera: Pteromalidae) was collected from this beetle (Daniel and Kumar, 1979).

3. Cigarette beetle *Lasioderma serricorne* F. (Coleoptera: Anobiidae)

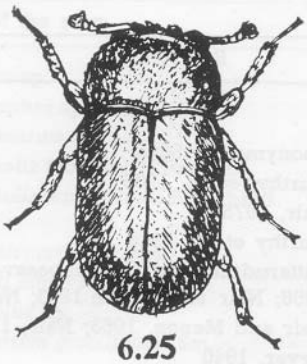
This is a widely distributed storage pest infesting stored arecanuts in Kerala and Karnataka. The adult beetle is reddish brown with shining hairs (Fig. 6.27). This beetle is found to infest stored arecanut almost throughout the year.

The adults and grubs damage the nuts by making tunnels within the nuts and reducing them to a powder (Nair and Oommen, 1969). It was observed that the life cycle of this insect was completed in 39–69 days.

A predatory bug was collected feeding on the grubs of this beetle. The parasite *A. calandrae* also was found on arecanuts infested by this pest.

4. Rice moth *Corcyra cephalonica* (Stainton) (Lepidoptera: Galleriidae)

The caterpillars of this moth construct galleries of silk and frass over stored nuts, remain within and feed on them (Fig. 6.28) (Nair and Oommen,



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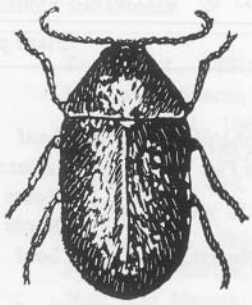
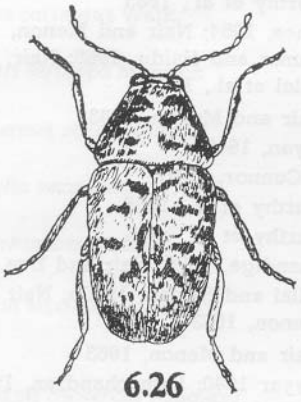


6.27



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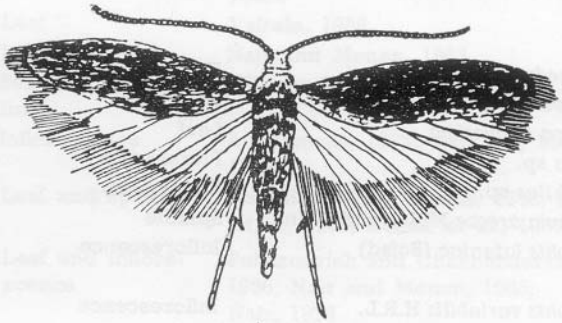

6.28

Fig. 6.25 Adult of *Coccotrypes carpophagus*. Fig. 6.26 Adult of *Araecerus fasciculatus*.
Fig. 6.27 Adult of *Lasioderma serricorne*. Fig. 6.28 Adult of *Corcyra cephalonica*.

1969; Daniel and Kumar, 1979). Nair and Oommen (1969) recommended the use of jute bags soaked in 1% suspension of DDT or 0.1% lindane for storing arecanuts and found that they remained free from insect infestation for up to six months. Phostoxin tablets used at the rate of 800 g per 1000 cm^3 are also effective in controlling stored arecanut pests.

Appendix 6.1. *Pests of arecanut seedlings and palms.*

Name of the pest	Plant parts infested	Reference
INSECTS		
Acanthopsyche plagiophelphs Hampson	Leaf	Anonymous, 1969a
Acicnemis praembulans Fst.	Inflorescence	Murthy, et al., 1965
Anomala varians Ol.	Roots and leaf	Nair, 1975
Anomelochela sp.	Roots	Murthy et al., 1965
Aonidiella orientalis (Newst.)	Leaf	Puttarudriah and Channabasavanna, 1956; Nair and Menon 1963; Nair, 1975
Aspidiotus destructor Sign.	Leaf	Nair and Menon, 1963; Nair, 1975
Aspidiotus ficus Ash	Leaf	Ayyar, 1940
Aulacophora sp.	Inflorescence	Murthy et al , 1965
Aularches miliaris Linn.	Leaf	Jones, 1954; Nair and Menon, 1963, Kumar and Naidu, 1965; Nair, 1975; Pillai et al., 1976
Batrachedra sp.	Floral parts	Nair and Menon, 1963
Brontispa mariana	Leaf	Bryan, 1949
Brontispa longissima	Leaf	O'Connor, 1940
Bruchus sp.	Floral parts	Murthy et al., 1965
Carpophilus sp.	Floral parts	Murthy et al., 1965
Carvalhoia arecae Miller and China	Spindle	Khandige, 1955; Nair and Das, 1962
Cerataphis lataniae (Boisd)	Inflorescence	Pillai and Kurian, 1959b; Nair and Menon, 1963
Cerataphis variabilis H.R.L.	Inflorescence	Nair and Menon, 1963
Chionaspis dilatata Gr.	Leaf	Ayyar 1940; Ramachandran, 1951; Nair, 1975
Coccus acutissimum Gr.	Leaf	Nair and Menon, 1963; Nair, 1975
Coccus hesperidum Linn.	Leaf	Puttarudriah and Channabasavanna, 1956; Nair and Menon 1963; Nair, 1975
Contheyla rotunda H.	Leaf	Sathiamma and Bhat, 1972
Cryptothelia sp.	Foliage	Nair and Menon, 1963
Diocalandra frumenti F.	Stem and inflorescence	Murthy et al., 1965; Nair and Menon, 1963
Diocalandra stigmaticollis Gyll.	Stem and inflorescence	Murthy et al., 1965; Pillai and Kurian 1959b; Nair and Menon, 1963; Nair, 1975
Dioryctus sp.	Inflorescence	Murthy et al., 1965
Dysmicoccus brevipes (Ckll.)	Collar of seedlings	Rao and Bavappa, 1961; Nair, 1975
Elymnias caudata Butl.	Seedlings	Nair, 1964b; Nair, 1975
Euproctis semisignata Walk.	Leaf and inflorescence	Nair, 1975
Gossyparia sp.	Inflorescence	Nair and Menon, 1963; Nair, 1975
Hemerocampa sp.	Leaf	Nair and Menon, 1963; Nair, 1975
Icerya aegyptiaca (Doug).	Leaf and inflorescence	Puttarudriah and Channabasavanna, 1957b, Nair and Menon, 1963; Nair, 1975

Name of the pest	Plant parts infested	Reference
Lepidiota sp.	Roots	Rao et al., 1961; Murthy et al., 1965
Lepidosaphes sp.	Leaf	Nair and Menon, 1963; Nair, 1975
Leucohimatum sp.	Inflorescence	Murthy et al., 1965
Leucopholis burmeisteri Brenske	Roots	Anonymous, 1967
Leucopholis lepidophora Blanchard	Roots	Puttarudriah and Channabasavanna, 1957b; Murthy et al, 1965
Mehasena corbetti Tams.	Leaves	Anonymous, 1929
Manatha albipes Moore	Foliage	Pillai and Kurian, 1959b; Nair, 1975
Melanoplus sp.	Foliage	Nair and Menon, 1963; Nair, 1975
Monomorium gracillimum Sm.	Foliage and inflorescence	Anonymous, 1962; Nair and Menon, 1963
Morismus carinatus Walk.	Young palms	Kumar and Naidu, 1965; Anonymous, 1969a
Nephantis serinopa Meyrick	Leaf	Valsala, 1958
Nygmia	Inflorescence	Nair and Menon, 1963
Odontotermes obesus (Ramb)	Seednuts and seedlings	Pillai and Kurian, 1959b; Nair, 1975
Oecophylla smaragdina F.	Inflorescence	Anonymous, 1962; Nair and Menon, 1963
Oryctes rhinoceros Linn.	Leaf and spindle	Nambiar, 1949; Valsala, 1958; Murthy et al., 1965; Kumar et al., 1967
Parlatoria mytilaspiformis Gr.	Leaf and inflorescence	Puttarudriah and Channabasavanna, 1956; Nair and Menon, 1963; Nair, 1975
Phenacaspis cockerelli (Cooley)	Leaf	Nair, 1975
Phenacaspis dilatata Green	Leaf	Nair and Menon, 1963
Phyllophaga fissa	Roots	Anonymous, 1971a
Pinnaspis aspidistrae Sign.	Leaf and inflorescence	Ayyar, 1940; Pillai and Kurian, 1959b; Nair and Menon, 1963; Nair, 1975
Pinnaspis buzi (Bouche)	Leaf	Nair, 1975
Pinnaspis dracoenae Cooley	Leaf	Nair, 1975
Pinnaspis strachani Cooley	Leaf and inflorescence	Nair and Menon, 1963; Nair, 1975
Porthesia sp.	Leaf	Nair and Menon, 1963
Promecotheca cumingi Baly	Leaf	Lever, 1951
Proutista moesta Westw	Leaf	Nair and Menon, 1963
Pseudococcus citriculus (Green)	Leaf and inflorescence	Nair, 1975
Pyroderces sp	Floral parts	Nair and Menon, 1963; Nair, 1975
Ouadraspidiotus sp.	Leaf	Nair, 1975
Rostrococcus iceryoides (Green)	Leaf and inflorescence	Nair, 1975
Rhipiphorothrips cruentatus Hood	Leaf	Puttarudriah and Channabasavanna, 1956; Pillai and Kurian, 1959; Nair, 1975
Rhynchophorus ferrugineus Fab.	Stem	Pillai and Kurian 1959b; Murthy et al., 1965

Name of the pest	Plant parts infested	Reference
Rhynchophorus sp.	Inflorescence	Murthy et al., 1965
Saissetia hemisphaericum	Leaf	Coleman and Rao, 1918
Saissetia sp.	Leaf	Nair and Menon, 1965; Nair, 1975
Spatulifimbria gresia Hering	Leaf	Anonymous, 1969a
Thrips hawaiiensis Morgan	Flower	Nayar et al., 1976
Thyridopteryx sp.	Foliage	Nair and Menon, 1963; Nair 1975
Tirathaba mundella Walk.	Inflorescence	Anonymous, 1962; Nair and Menon 1963; Nair and Rawther, 1969
Tirathaba rufivena Walk.	Inflorescence	Lever, 1937
Wallacea palmarum Gestro	Young leaves	Anonymous, 1929
Xyleborus habercorni Egg.	Stem	Murthy et al., 1965
Xyleborus perforans Woll.	Stem	Seshadri, 1968
Xylotrupes gideon Linn.	Fronds	Anonymous, 1970
MITES		
Dolichotetranychus sp.	Tendernuts	Sadanandan and Antony, 1973
Lasioseius sp.	Inflorescence	Nair and Rao, 1964
Neocypholaelaps stridulans Evans	Inflorescence	Nair and Rao, 1964
Oligonychus biharensis Hirst	Leaf	Puttarudriah and Channabasavanna, 1956
Oligonychus indicus Hirst	Leaf	Puttarudriah and Channabasavanna, 1956
Raoiella indica Hirst	Leaf	Puttarudriah and Channabasavanna, 1956
Tetranychus fijiensis Hirst	Leaf	Daniel, 1977
Amblyseius ovalis Evans	Leaf	Prasad, 1974
VERTEBRATE PESTS		
Squirrels	Tendernuts	Ramachandran, 1951; Pillai and Kurian, 1959b; Naidu, 1962
Rats	Tendernuts	Coleman and Rao, 1918; Pillai and Kurian, 1959b; Nair and Menon, 1963
Bats	Fruits	Pillai and Kurian 1959b; Daniel and Kumar, 1976
Monkeys	Fruits	Nambiar, 1949; Pillai and Kurian, 1959b; Daniel and Kumar, 1976
Woodpecker	Stem	Nair and Menon, 1963

Appendix 6.2. *Pests of stored arecanut*

Name of the pest	Family	Reference
Araecerus fasciculatus DeG.	Anthribidae	Ayyar, 1940
Coccotrypes carpophagus H.	Scolytidae	Oommen and Nair, 1968
Lasioderma serricorne F.	Anobiidae	Nair and Oommen, 1969
Corcyra cephalonica (Stainton)	Galleriidae	,,
Setomorpha rutella Zell.	Tineidae	,,

Name of the pest	Family	Reference
Ephestia cautella (Walk)	Phycitidae	Nair and Oommen, 1969
Tribolium castaneum Hest.	Tenebrionidae	,,
Alphitobius piceus 01.	,,	,,
Microcrypticus scriptipennae F.	,,	,,
Cryptolestes pusillus Schonh	Cucujidae	,,
Tyrophague putrescentiae Schrank	Acaridae	,,
Carpophilus mutilatus Er.	Nitidulidae	,,
Ahasverus advena Waltl.	Cucujidae	,,
Attagenus gloriosae F.	Dermestidae	,,
Carpophilus pilosellus Mots.	Nitidulidae	Daniel and Kumar, 1979
Thaneroclerus buquet (Lefebvre)	Cleridae	,,
Sitophilus oryzae. L.	Curculionidae	,,
Proceus sp. (?) depressus Woll.	,,	,,
Psocid sp. (undetermined)	Psocidae	,,
Pseudoscorpion	Pseudoscorpionidae	,,
A mite (undetermined)	Cheyletedae	,,

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7

DISEASES

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Arecanut palm is affected by a number of diseases during different stages of its growth and development. About 20 diseases causing varying degrees of damages to the palm have been recorded in India. They are associated with 40 pathogenic and non-pathogenic forms of fungi and one bacterium. Based on the extent of damage and nature of disease, yellow leaf disease, *mahali, anabe,* inflorescence die-back and button shedding are considered to be the major diseases. Among the less serious diseases, the bud rot, bacterial leaf stripe, stem breaking and seedling diseases are important, since some of them at times occur epiphytotically in localised places and cause heavy losses. Etiology of diseases like *mahali,* bud rot and *anabe* is clearly known, while that of others like yellow leaf disease and *band* are uncertain. Microbial infestation of processed nuts is an important post-harvest problem causing considerable deterioration in the quality of the produce.

I. Diseases affecting adult palms

1. Yellow leaf disease

The yellow leaf disease (YLD) remains today as the most serious malady affecting the crop. This disease known in Malayalam as *kattuveezhcha* was reported from Muvattupuzha, Meenachil and Chalakudi areas in Kerala about a century

back (Nambiar and Sreenivasan, 1951). In earlier years, it was felt that YLD was more or less similar to the leaf and root diseases of coconut (Nambiar, 1949). In the *Malnad* areas of Karnataka the disease is known as *chandiroga* (Dastagir, 1963, 1965). The malady does not kill the palm outright but is only debilitating in nature.

i. *Crop loss*

A preliminary survey conducted during 1959–'60 showed that the disease had spread to all parts of Kerala with a maximum incidence of 90% in Quilon district (Anonymous, 1960b). The disease was also reported from the central regions of Maharashtra and Tamil Nadu (Anonymous, 1963b).

A comprehensive survey was undertaken in 1976 in the disease affected areas of Kerala and Karnataka. The results revealed that the malady is prevalent in almost all the districts of Kerala and in parts of Chickamagalur district of Karnataka. The results are presented in Table 7.1 (George, Nayar and Rawther, 1982, unpublished).

Table 7.1. *Spread of yellow leaf disease in Kerala and Karnataka*

State/district	Area under arecanut in '000 ha	Percentage of area affected by YLD
KERALA		
Cannanore	16.58	1.20
Kozhikode	8.10	0.70
Malappuram	15.50	Negligible
Palghat	3.70	Not available
Trichur	15.10	6.30
Idukki	1.70	97.00
Ernakulam	7.80	34.10
Kottayam	5.40	94.30
Alleppey	5.10	Not available
Quilon	9.20	75.40
Trivandrum	4.50	71.80
Total	*92.68*	*35.80*
KARNATAKA		
Chickamagalur (Koppa and Sringeri Taluks)	–	28.4

Thorough and systematic observation was made with respect to the pattern and spread of the disease at the CPCRI Research Centre, Palode located in a predominently affected area. Seedlings planted in 1961 in virgin soil manifested symptoms in 1968 and thereafter within a period of four years 80% of the palms contracted the disease (Rawther and Abraham, 1972). Though the spread was rapid, it did not follow any definite pattern.

Fig. 7.1 Yellow leaf disease affected palms

Studies on YLD affected palms revealed a reduction in yield to the extent of 50% over a period of three years immediately following the disease incidence. An average of 4% reduction in leaf fall was also noticed on account of the disease during the three year period (Anonymous, 1976).

ii. *Symptoms*

Nambiar (1949) observed the symptoms of the disease as yellowing of the leaves and shedding of both mature and immature nuts. The endosperm of the diseased nut has a blackish appearance and is soft to touch, which renders it unsuitable for consumption and fetches only very low price in the market. According to Menon (1963a), the first visible signs are translucent spots, 1–3 mm in diameter on the growing spindle. Brown necrotic streaks running parallel to the lamina are present in the unfolding leaves. As the leaves develop, yellowing starts from the tips of leaflets, gradually extending to the middle of the lamina. This chlorosis could be distinguished from the physiological yellowing by the abrupt demarcation between the green and yellow regions in the diseased leaf. Subsequent studies have shown that the first visible symptom is the yellowing at the tips of leaflets in two or three leaves of the outermost whorl (Rawther, 1976).

One or two leaflets in any part of the crown or the entire foliage may be affected by the disease. Tips of the chlorotic leaves eventually dry up. In the advanced stage, leaves are reduced in size, stiff and pointed, closely bunched and abnormally puckered (Fig. 7.1). Ultimately the crown falls off leaving a bare trunk. The root system of the palm is also affected. The lateral roots are not produced as profusely as in healthy palms. Tips and absorbing regions of young roots turn dark and gradually rot. The affected fruits fall off in large numbers.

Though endosperm discolouration is associated with foliar yellowing in majority of cases, palms exhibiting foliar yellowing sometimes produce normal nuts. Further, all the nuts produced in a bunch of a diseased palm may not show kernel discolouration (Rawther, 1976). Palms with normal green foliage standing among diseased ones were also observed to produce nuts with blackened kernel.

Nayar (1968) observed multi-nucleate cells, deranged tissue differentiation and palisade cells blocked with dark brown pigments in various stages of degeneration in leaves of affected palms. She also observed extensive degeneration in the phloem of the affected stem and leaves. Medullary rays were found disturbed and accumulation of starch grains was observed indicating impaired translocation. Nair (1976) found that the diseased leaves possessed smaller

epidermal cells, stomatal pores and midrib parenchyma cells. Blocking of xylem vessels of the older leaves of diseased palms, degeneration of the cortex and presence of tyloses in the xylem were also noticed in the diseased roots.

A formula for quantifying the disease was evolved after studying the association of the various symptoms in more than 2000 palms (George, Mathew and Nagaraj, 1980). Due weightage was given to foliar yellowing, necrosis and reduction in the size of the whole crown. In the formula

$$\text{I (intensity)} = \left(\frac{Y+N}{L}+R\right) \times 10$$

Y and N are the sum of grade points for yellowing and necrosis, L is 50% number of leaves in the crown and R is the grade point for reduction in size of the crown for the whole palm.

iii. *Etiology*

a. Fungi

A number of fungi like *Ceriospora arecae, Exosporium arecae, Leptosphaeria* sp., *Diplodia* sp., *Phyllosticta* sp., *Dimerosporina* sp., and *Trametes corrugata* were isolated from the diseased leaves (Menon, 1959a; Anonymous, 1963b). Roots of diseased palms yielded *Trichoderma* sp., *Pestalotia* sp., *Aspergillus sp., Penicillium* sp., *Fusarium* sp., *Colletotrichum* sp., *Acremonium* sp., etc. (Anonymous, 1963b). *Fusarium* sp., *Acremonium* sp. and *Colletotrichum* sp. were not pathogenic on inoculation to seedlings (Anonymous, 1963b, 1976). Species of *Pythium* and *Phytophthora* were isolated from the roots of disease affected palms using selective media (Rawther, T. S. S. 1982, personal communication).

b. Bacteria

Srivastava, Rao and Mohan (1970) reported bacterial streaming associated with YLD affected roots. Out of the two distinct forms of bacteria, one was tentatively identified as *Pseudomonas* sp. One and a half year old arecanut seedlings planted in heat sterilized soil in pots on inoculation with bacteria isolated from disease affected roots for a period of $2\frac{1}{2}$ years did not produce any disease symptoms (Anonymous, 1975).

c. Virus and mycoplasma

Paper chromatographic studies (Menon, 1961a) indicated that some proteins or their sub-units were present in diseased areca palms which were absent in the healthy ones. Serological investigation with crude arecanut antigen and disease specific rabbit antiserum showed that there was precipitation reaction,

indicating antibody formation. Menon (1960a) therefore suggested the possibility of a virus or virus like organisms being involved in the disease. Menon (1963a) transmitted yellow leaf disease to indicator plants *viz., Jatropha curcas, Canavalia ensiformis* and *Vinca rosea* using partially clarified leafsap.

Electron microscopic tests failed to show the presence of virus like particles (Raychaudhuri, S. P., 1966, personal communication). Nayar (1971, 1976) cultured mycoplasma like organism (MLO) from bits of diseased yellow leaf. Numerous colonies were produced in solid plate transfers from liquid cultures. Cross inoculation with rabbit antiserum using double cell diffusion technique showed that the areca antigen reacted against sandal spike-specific rabbit antiserum (Nayar, 1971).

Further, electron microscopic studies (Nayar and Seliskar, 1978; Seliskar and Wilson, 1981) showed the presence of MLO in the young sieve elements of YLD affected arecanut palms in Kerala and Karnataka. Diseased palms treated with the antibiotics like chlortetracyclin HCl (aureomycin) and tetracycline HCl (achromycin) failed to ameliorate the disease symptoms (Rawther, 1976).

d. Mites

Khandige, Patel and Bavappa (1957) reported association of mites with the yellow leaf. Menon (1960b) distinguished the yellowing caused by mite from the foliar yellowing due to yellow leaf disease.

e. Nematodes

Nair (1964) observed the presence of nematodes *Meloidogyne javanica, Helicotylenchus* sp. and *Tylenchorhynchus* sp. in the root zone of yellow leaf affected palms at Palode. Weischer (1967) recorded seven genera of plant parasitic nematodes from a few soil samples collected from the root zone of healthy and diseased palms.

Among the twenty-two genera of plant parasitic nematodes isolated from the root zone of healthy and disease affected palms, *Radopholus similis* was present in 111 out of 218 root samples. The occurrence of nematodes belonging to genera other than *Radopholus* in small numbers in samples may not be of any significance. Koshy, Sosamma and Sundararaju (1976) could not find any correlation between the presence of *R. similis* and the yellow leaf disease.

In a recent survey conducted in the healthy and yellow leaf affected arecanut gardens in Koppa, Sringeri, Sullia, Thirthahalli, Narasimharajpura and Somavarpet

in Karnataka state, 7/17 (41.2%) root samples from healthy and 16/20 (80%) from disease affected palms yielded *R. similis*. *R. similis* was also recorded in 7/17 (41.2%) and 14/20 (78%) soil samples collected from healthy and disease affected arecanut gardens respectively (Sundararaju and Koshy, 1980, unpublished).

f. Soil and nutritional factors

Water logging was considered to be one of the predisposing factors for the disease incidence (Anonymous, 1960b). Application of fertilisers, improved the condition of diseased palms (Anonymous, 1967). Menon and Kalyanikutty (1961) reported a reduction in the intensity of foliar yellowing when sprayed with salts of magnesium and manganese. Qualitative tests on diseased arecanut leaves recorded low pH, more water and HCl soluble iron. The high CaO/MgO ratio obtained was attributed to low content of magnesium in the diseased tissues (Anonymous, 1967). Diseased leaves had more silica, phosphorus and potash (Anonymous, 1964).

The extensive surveys in the nutrient status of healthy and disease affected gardens of Kerala and Karnataka were carried out in 1969 and 1974 (Mohapatra, Bhat and Harishukumar, 1976). No significant difference was noticed in the nutrient contents in leaves and soil between healthy and diseased samples. However, some difference in nutrient status was noticed between samples of Kerala and Karnataka. Soils of both the states were high in organic matter, low to medium in available P and K and contained adequate levels of exchangeable Fe, Mn, Zn and Cu. Soils from Karnataka were neutral in reaction while soils from Kerala were slightly acidic. The results of analysis of soils from healthy and disease affected areas of Kerala and Karnataka are given in Table 7.2 (Mohapatra et al., 1976).

Velappan (1969) observed that deficiencies of nitrogen, phosphorus and magnesium had some relationship with the disease. In the initial stages of the development of the symptoms, nitrogen, phosphorus and magnesium were found deficient but potassium and calcium were present in normal quantities in the affected palms (Anonymous, 1971). Yadava, Mathai and Vellaichamy, (1972) examined the role of major nutrient deficiencies in the symptom expression of the disease in a pot culture experiment, but could not produce any typical symptoms by this method. Root feeding of iron solution (as ferrous sulphate) did not produce symptoms similar to that of the disease (Mathai, 1976). Leaf tissues of healthy palms in general showed higher accumulation of nutrients (N, P, K and Mg) when compared with the diseased (Yadava, Mathai and Vellaichamy, 1973).

Table 7.2. *Mechanical and fertility constituents of soils from yellow leaf disease affected and healthy areas of Kerala and Karnataka states (mean values expressed on air dry basis)*

Constituents	Kerala (Trivandrum and Quilon)				Karnataka (Chickamagalur and Dakshina Kannada)			
	Category							
	Apparently healthy palm		Diseased palm		Healthy palm		Diseased palm	
	Low lying	High elevation	Low lying	High elevation	Low lying	High elevation	Low lying	High elevation
Sand (%)	72.48	62.60	69.92	65.91	59.68	55.84	56.77	58.45
Silt (%)	8.42	8.92	8.87	8.39	15.52	16.85	16.22	17.86
Clay (%)	19.08	26.34	21.20	25.68	24.79	27.29	27.26	23.68
pH (H_2O)	5.66	5.60	5.58	5.58	6.34	6.36	6.54	6.14
pH (KCl)	4.39	4.27	4.31	4.26	5.13	5.16	5.30	5.06
Organic carbon (%)	0.82	0.91	0.84	0.96	1.27	1.32	1.38	1.10
Available P_2O_5 (ppm)	12.17	6.06	9.23	6.01	21.46	14.84	18.95	9.05
Available K_2O (ppm)	66.52	84.00	75.81	84.90	144.10	163.18	153.18	130.80
Exchangeable Ca (ppm)	179.50	215.00	186.20	185.40	692.90	720.30	834.00	497.50
Exchangeable Mg (ppm)	47.90	68.80	45.20	59.00	173.10	190.90	220.10	152.40
Exchangeable Al (ppm)	54.35	64.53	59.95	68.84	1.59	0.10	0.45	Trace
Extractable Al (ppm)	66.97	97.48	83.30	105.60	41.21	42.10	48.23	37.84
$Fe^2 + Fe^3 +$ (ppm)	19.53	14.77	23.98	16.16	14.84	12.80	12.90	12.36
Exchangeable Mn (ppm)	8.03	8.83	7.65	8.82	12.50	17.47	15.68	16.30
Dithizone extractable Zn (ppm)	1.03	1.08	1.15	0.98	2.32	2.36	2.49	2.22
Exchangeable Cu (ppm)	2.04	1.92	1.99	1.97	3.94	4.02	3.57	3.32

The amino acid content (cystine, aspartic acid and threonine) of diseased leaves decreased in the early and middle stages of the disease and enhanced in advanced stages. On the other hand, lysine and arginine contents of leaves progressively increased with advancement of disease. Glutamic acid was absent in inflorescence and nuts of healthy palms and present in the diseased. Serine, arginine and threonine commonly found in arecanut stems decreased with increase in intensity of disease. Proline, cystine and histidine seen in the roots of healthy palms began to fall with the onset of disease. Thus an impaired amino acid metabolism is the characteristic feature of the disease (Nair, 1969).

iv. *Control*

a. Chemical control

Disease affected palms were given basal treatment of seven chemicals *viz.*, Brassicol, Vitavax, Bavistin, Cupramar, Blue copper–50, Furadan and Metham sodium for a period of five years. None of the treatments had any ameliorative effect on disease symptom, though palms treated with Blue copper–50, Cupramar and Furadan recorded increase in yield over the pretreatment to the tune of 31, 25 and 29 per cent respectively (Chandramohan, 1979). Diseased palms treated with tetracycline by root feeding and stem injection did not have any effect. Basal application of aureofungin solution also gave only negative results (Rawther, 1976).

A field trial conducted in the diseased tracts of Palode to study the effect of major and minor nutrients and irrigation showed that none of the treatments was effective in controlling the disease (Rawther and Abraham, 1972). A comprehensive package plan trial was laid out in Kerala and Karnataka involving all major and minor nutrients (Nagaraj, Mathai and Vellaichamy, 1976). Though the yield of the treated palms registered a decrease in majority of the treatments in Kerala, treatments NPK + lime, NPK + lime + boron and NPK + lime + zinc registered 15–19% increase in yield.

Palms treated with Hogland's solution showed an initial reduction in foliar yellowing but the improvement was not consistent (Anonymous, 1979). Foliar application of urea, diammonium phosphate and manganese sulphate did not show any ameliorative effect on the condition of the diseased palms (Rawther, T. S. S. 1982, personal communication).

b. Disease management

In view of the uncertain etiology, non–lethal nature of the disease and the absence of known remedial measures, it was felt necessary to evolve proper

management practices to contain the disease to the maximum extent possible. A mixed cropping experiment involving regular organic recycling in a disease affected 15-year old arecanut garden was conducted. Cowpea and Guinea grass were mix-cropped with arecanut. The organic manures for recycling were obtained from a dairy maintained. None of the treatments had any specific influence on the expression of disease symptoms. However, there was a general improvement in yield in all the treatments. Further it was noticed that the effect of the treatments on the microbial population was not consistent (Rawther, et al., 1979).

An observational trial to study the effect of the application of high doses of fertilisers (100g N, 160g P_2O_5 and 140g K_2O/ palm/year) along with 4 kg of dolomite, and organic manures and irrigation failed to give positive results (Rawther, T.S.S. 1982, personal communication).

c. Disease reaction of cultivars

Fifty accessions of indigenous and exotic collection of arecanut were planted from 1961 onwards at the CPCRI Research Centre, Palode – a diseased area – in order to assess their field reaction against yellow leaf. All of them except *Areca triandra* began to exhibit disease symptoms after about eight years of planting. Only a few instances of doubtful cases of disease incidence have been noticed in *A. triandra.*

2. *Mahali*

Mahali (heavy devastation) or *koleroga (kole* = rotting, *roga*=disease) is the most dreaded disease occurring in all the arecanut growing regions receiving heavy rainfall. Butler (1906) first recorded the disease in the erstwhile Mysore state. The disease was reported from the present Dakshina Kannada and Uttara Kannada districts of Karnataka as well as in small pockets of Malabar and Cochin areas (Coleman, 1910).

The exact crop loss caused by the disease is not available till now. However, an annual loss of 10–75% in parts of Karnataka, Kerala and Maharashtra or total destruction of crop in individual gardens have been recorded (Coleman, 1910; Coleman and Rao, 1918; Nambiar, 1956; Kamat, 1956; Anonymous, 1960a). In the year 1978, the *koleroga* disease was rampant and crop loss ranged from 50–90% (Reddy and Anandaraj, 1980).

i. *Symptoms*

Butler (1906) described the disease with the characteristic symptoms of rotting and excessive shedding of immature nuts. Coleman (1910) described the symptoms with prolific illustrations in his pioneering work on this disease. The first visible symptom is the appearance of water soaked lesions on the surface of affected nuts. The infected nuts lose their lustre. The lesions gradually spread covering the entire nuts which rot and shed from the calyx (Fig. 7.2). A felt of white mycelial mass develops on the fallen nuts (Butler, 1906; Coleman, 1910). As the disease advances the fruit stalks and rachis of inflorescence are also affected (Fig. 7.3A) (Sundararaman and Ramakrishnan, 1928; Marudarajan, 1950a). Affected nuts are lighter in weight and possess large vacuoles and dark brown radial strands internally. Infections occurring later in the season result in drying

Fig. 7.2 *Koleroga* infected bunches

up of nuts without shedding (Marudarajan, 1950a). These nuts are often colonised by saprophytes like *Gloeosporium* sp. and are called 'dry mahali' in central Kerala. Apart from the quantitative loss by shedding of nuts at its various stages of development, the infected nuts are unsuitable for chewing due to deterioration in quality.

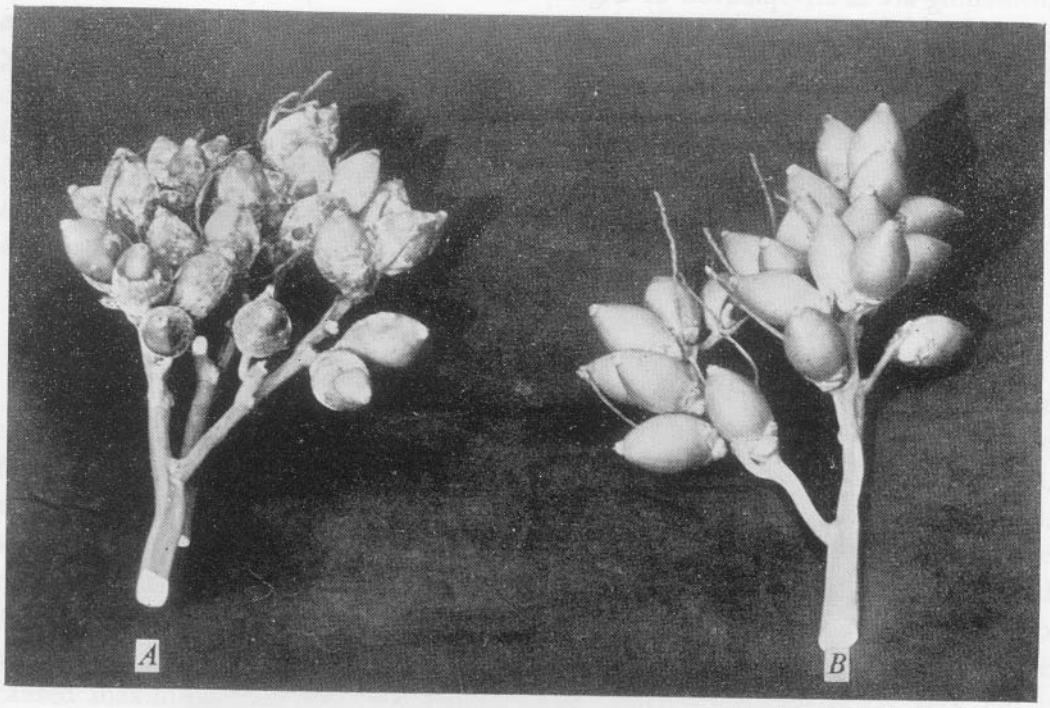

Fig. 7.3 A. Portion of the bunch showing white mycelial growth of *Phytophthora*. B. Portion of a healthy bunch.

ii. *Etiology*

The pathogen was first described as *P. omnivora* De Bary by Sydow and Butler (1907) and as *P. omnivora* var. *arecae* by Coleman (1910). Pethybridge (1913) observed that the fungus was quite different from De Bary's *P. omnivora* and hence named it as *P. arecae* Peth.

The mycelium of the fungus is coenocytic, but sparsely septate in the older stages. It is inter and intra-cellular, occasionally branched with finger like haustoria. The hyphal diameter varies from 8 to 9μ (Coleman, 1910). The fungus grows and sporulates better on steamed corn meal agar (Tucker, 1931).

Asexual reproduction is by production of sporangia and chlamydospores. Sporangiophores are about 2.5μ wide and irregularly sympodial. Sporangia are broadly ellipsoid or obturbinate to nearly spherical, mostly in the range of 40–50μ × 35–40μ, maximum being 70μ × 48μ (l:b ratio=1.1–1.4:1) (Fig.7.4). They are deciduous with a pedicel length of 1–6μ. The papilla and apical thickening are hemi-spherical or slightly less. The chlamydospores are variable in number, sometimes absent or rare and never abundant, the size being 35–40μ in diameter (maximum 60μ) with a wall thickness of 1μ (Tucker, 1931; Waterhouse, 1963; Newhook, Waterhouse and Stamps, 1978).

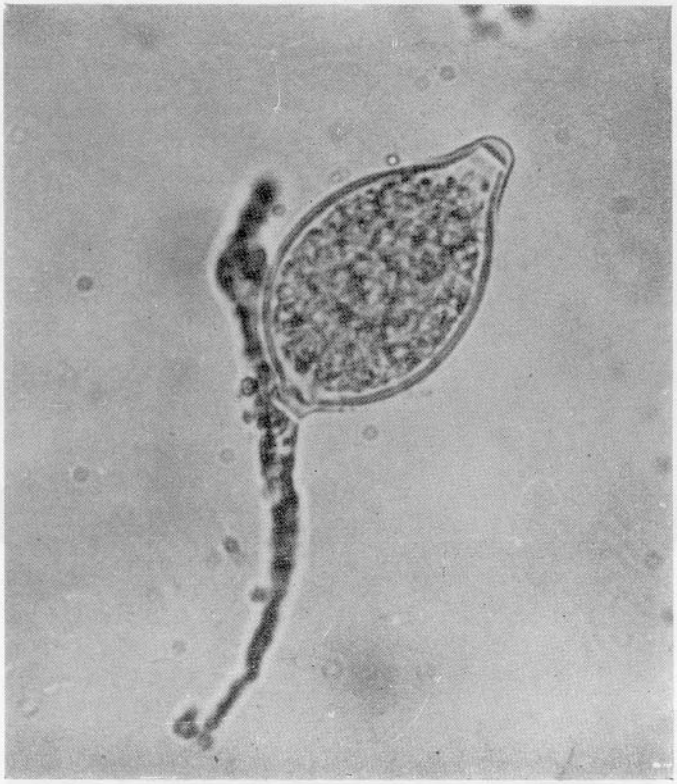

Fig. 7.4 Sporangium of *P. arecae*

Sexual reproduction is oogamous. Oogonia are 30μ in diameter, rarely over 35μ (maximum being 40μ), with smooth wall. Oospore nearly fills the oogonium and have a diameter of 28μ with a 3μ thick wall. Antheridia are always amphigynous, frequently broader than its length, with a size of 14μ × 15μ (Waterhouse, 1963).

Sundararaman and Ramakrishnan (1928) could not observe oospores in nature. This was due to the presence of + and — strains which are localised (Uppal and Desai, 1939). Coleman (1910) observed oospore production on inoculated arecanuts, *Cereus formosus, Clarkia elegans* and Desai (1950) on fresh bean agar. Homothallic nature of the fungus was observed by Narasimhan (cf, Anonymous, 1932) Ramakrishnan (cf, Anonymous, 1954b) and Ramakrishnan and Seethalakshmi (1956), while it was reported as heterothallic by Ashby (1929), Venkatarayan (1932) and Marudarajan (1941). The formation of oospores was observed only in the mixed cultures of *Phytophthora* from arecanut with isolates from coconut, palmyrah and rubber, but not among the isolates from arecanut (Marudarajan, 1941). Oospore formation was also reported in mixed cultures of *P. arecae* and *P. meadii* (Ashby, 1929) and in paired cultures of *P. arecae* and *P. infestans* (Gallegly, 1964).

iii. *Epidemiology*

Rain plays an important role in the initiation and spread of the disease since low temperature and high humidity are favourable for the growth of the fungus (Coleman, 1910). Soon after the South West Monsoon breaks in June, the disease makes its appearance. Heavy rain fall with constant humid condition, wind, low temperature (20–23°C), alternate sunshine and rainfall, favour disease development (Coleman, 1910; Narasimhan, 1922; Kamat, 1956). Reddy and Anandaraj (1980) attempted to correlate the intensity and spread of the disease to the rainfall and temperature for a period of nine years and found that the disease caused maximum crop loss (50.9%) in 1978, when the rainfall was very heavy (5088.6 mm). The intensity of *mahali* is very severe in plantations situated in valleys or those surrounded by thick belts of trees (Kamat, 1953) or with intercrops resulting in high humid conditions.

The zoospores germinate in films of water and penetrate the surface of the nut through stomatal openings. In about four days, the fungal growth emerges out with sporulation. The subsequent spread depends upon the heavy rains and wind, which help the dispersal of the spores through splashing (Coleman, 1910).

The over-summering of the fungus is through resting spores probably present in the diseased parts of the host as well as in the upper layers of the soil (Coleman, 1910). Bud rot affected areca palms remaining in the garden may serve as potent source of primary infection.

iv. *Control*

Attempts to control *mahali* by providing covers to arecanut bunches made of arecanut leaf sheath called *Kotte* in *Malnad* region or covers made of grass called *Karada* in other regions of Karnataka were in vogue, before the scientific plant protection was introduced. These covers neither helped in preventing, nor in eradicating the disease (Coleman, 1910; Anonymous, 1954a; Rao, 1960). Coleman (1910) was the first to recommend spraying 1% Bordeaux mixture with resin and washing soda as adhesive to control the disease. Various workers tested the efficacy of different adhesives and spreaders with Bordeaux mixture with good results (Narasimhan, 1924; Anonymous, 1927). Potash alum with casein called Martin's Bordeaux mixture (Narasimhan, 1928a, 1928b) and vegetable oils from ground nut, gingelly, coconut or safflower (Anonymous, 1932; Thomas and Marudarajan, 1938; Rao, 1960) added to Bordeaux mixture before spraying, protected the palm from *mahali*. However, it was also shown that plain Bordeaux mixture without any adhesive was equally effective in controlling the disease (Thomas and Marudarajan, 1938) and therefore prophylactic spraying with neutral Bordeaux mixture (1:1:100) alone once before the onset of heavy South West Monsoon and a second application 40–45 days after has been recommended. If rain is persistent a third round of application may also be given at the same interval.

Spraying campaign against *mahali* was undertaken in Karnataka on payment basis (Anonymous, 1924) and an improved sprayer called 'Primus' was developed for the purpose (Anonymous, 1938a). A number of other chemicals such as mercurised copper oxychloride and Blitane were tested besides Bordeaux mixture. Spraying the bunches with copper oxychlorides did not check the disease in the field while it produced copper injury symptoms even at 0.5% concentration (Anonymous, 1969). Proprietory copper fungicides sprayed also could not protect the nuts as efficiently as Bordeaux mixture (Table 7.3). It could be seen from the data that the Bordeaux mixture spray gives maximum copper deposit initially, resulting in less disease incidence and maximum retention of copper on the nuts even after 40 days (Anonymous, 1969).

Besides the protective spraying against the disease, it is also necessary to reduce the inoculum potential by adopting phytosanitary measures such as collection and destruction of fallen nuts, removal of diseased bunches, tree tops and other plant parts in the field (Coleman, 1910) and eliminate alternate hosts.

Table 7.3. *Copper deposit on nuts sprayed with different fungicides*

Fungicides	Type of spray	Infection (%)	Copper deposit in μg/ml of washed nut (mean value)	
			1 day after spraying	40 days after spraying
Fycol 8E in water	Low volume	68	7.34	5.59
Fycol 8E in oil	,,	21	5.28	4.80
Oleocap in oil	,,	29	7.48	4.11
Fycol 8 in oil	,,	28	7.36	4.35
Bordeaux mixture	High volume	8	15.52	7.63

3. *Anabe roga* or foot rot

Anabe roga literally means a disease caused by a mushroom. Occurrence of the disease in Karnataka was recorded as early as 1807 by Buchanan (Buchanan, 1807). The same disease was mentioned as betelnut plague from Silhat (Butler, 1906). The *anabe* disease was prevalent in *Maidan* and semi-*Malnad* areas of Karnataka, causing heavy crop loss.

The disease has also been reported from parts of Tamil Nadu especially in Mettupalayam areas, Kerala and Assam (Anonymous, 1960a) Bengal (Sharples, 1928) and Nicobar Islands (Sangal, Mukerji and Singh, 1961).

The disease was observed in severe form in neglected, ill-drained and over crowded gardens (Venkatarayan, 1952). The intensity was more in hard black loamy and acid soils and soils of higher iron and lower calcium contents (Lalithakumari, 1969). Palms over 5-10 years are generally affected (Coleman and Rao, 1918). The disease is primarily soil-borne and spreads secondarily through air-borne spores (Venkatarayan, 1936).

Butler (1906) recorded 94% mortality in a neglected arecanut garden. The death rate of areca palms due to the disease in Karnataka has been estimated from 5% (Venkatarayan, 1936) upto 8% in neglected and water logged gardens (Naidu, Kumar and Sannamarappa, 1966). The incidence of the disease varied from 0.05 to 5.10% in Mettupalayam areas of Tamil Nadu (Anonymous, 1971).

i. *Symptoms*

The slight discolouration of the leaflets in the outer whorl of the leaves is the first observable symptom of the disease. This pale discolouration spreads to the whole leaf and the entire crown becomes progressively yellow with the outer whorl drooping down and covering the stem. Later the leaves in the inner

whorl also become yellow. The development of inflorescence and nuts is arrested. In the advanced stage, the infected palms exhibit the typical symptoms of a pronounced drought. Irrigation of the affected palms do not bring back the palms to normalcy. Subsequently the leaves dry up, droop and fall off leaving the bare stem. The infected brittle stem is easily broken off during heavy wind. The base of the stem shows brown discolouration and oozing of a dark fluid.

The fructification of the fungus (basidiocarp) with the characteristic bracket stage appears at the base of the trunk, and is called *anabe* (Fig. 7.5). The roots of the affected palms are brittle, discoloured and dried (Naidu et al., 1966.)

On cutting open the affected trunk, the infection could be traced upto one meter from the ground level. The central tissues of the affected portion of the

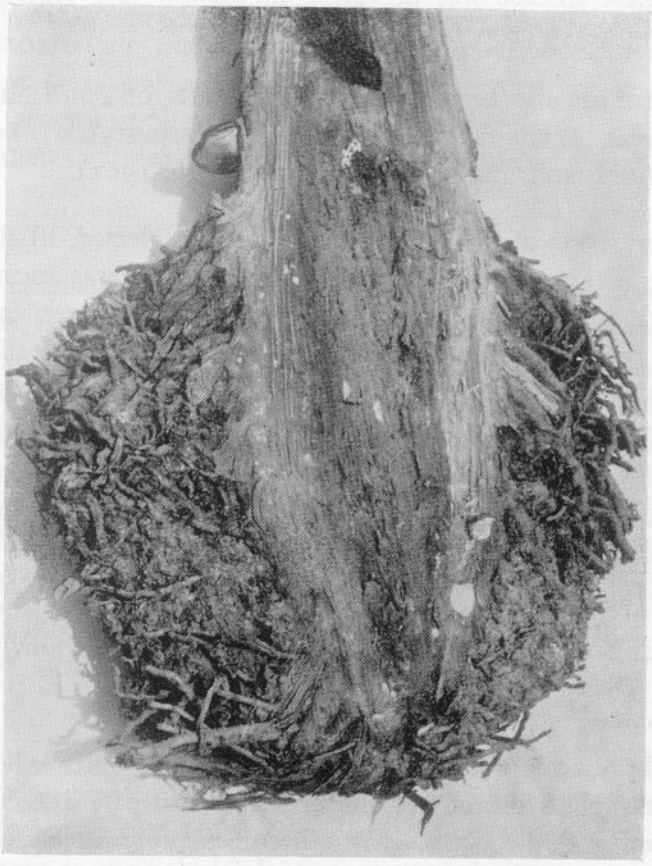

Fig. 7.5 *Anabe* affected stem showing developing sporophores

stem are generally dark brown in colour and emit a musty smell. The xylem and xylem parenchyma are completely broken down due to the invasion of fungus. This impedes the water supply to the top, resulting in pathological drought and death of the infected palm (Venkatarayan, 1936).

ii. *Etiology*

According to Coleman (1911) and Rao (1917) the disease is caused by a fungus *Fomes lucidus*. Venkatarayan (1936) reported that the causal organism as *Ganoderma lucidum* (Leys) Karst. The biology of the fungus was studied in detail by Bose (1930) and Menon (1963b). The fungus is heterothallic and tetrapolar, which reproduces sporophores having three types of spores and gastrospores in addition to chlamydospores (Banerjee and Sarkar, 1958, 1959). Chlamydospores are intercalary and terminal, golden yellow in colour and granular in content measuring $4-8\mu \times 4\mu$ in size (Menon, 1963b).

The hyphae are hyaline, $1-2\mu$ in diameter covered with a deposit of calcium oxalate crystals. Clamp connections occur profusely in older hyphae. The mycelium remains hyaline for about a month when the mats become dotted with drops of colourless fluid containing round, white, thin-walled conidia measuring $14\mu \times 20\mu$ in size. Patches of mycelium turn pale yellow, take up a russet tint very characteristic of the mature sporophores of *Ganoderma* found in nature. Luxuriant growth of the fungus was obtained in malt extract agar. The fungus grows well in a wide range of pH (3-9), the optimum being 4.5-6.5. Maximum mycelial growth of the fungus occurred at soil moisture of 40-80%. Production of fruiting bodies of the fungus was observed on wood pieces of *Mangifera indica* (Bose, 1930) as well as on saw dust medium enriched with 10% malt extract (Nambiar and Nair, 1973). The fungus produced many hydrolytic enzymes in culture (Venkatarayan, 1936).

The fungus has a wide host range infecting coconut (Butler, 1906), oil palm (Sharples, 1928), mango, arecanut, *Delonix regia, Pongamia glabra* and *Casuarina* (Bose, 1930, 1931; Venkatarayan, 1936), *Cassia,* tamarind (Anonymous, 1971) *Phyllanthus* sp. and *Acanthospermum* sp. (Anonymous, 1974). Being a slow growing fungus, *G. lucidum* does not always induce disease incidence on artificial inoculation (Anonymous, 1934).

iii. *Control*

A large number of chemicals have been tried against the disease with varied results. But none of them could eliminate the fungus from the soil or

control the spread of the disease effectively. Though Narasimhan (1940) found sulphur to be effective in controlling the disease, contrary results were obtained by Nair and Rao (1965). Mercurised copper oxychloride (Nair and Rao, 1965), Difolatan, Vitavax and aureofungin sol (Anonymous, 1973) were found to be effective against the pathogen in *in vitro* trials.

It is also known that *Trichoderma* sp., *Bacillus coagulans, Streptomyces* sp. and *Mucor* sp. are antagonistic to *G. lucidum* (Anonymous, 1963a, 1967; Menon, 1963b).

Since the disease is primarily soil–borne, its prevention is considered to be better than cure. Fresh planting of arecanut should be avoided in newly cleared jungle areas containing dead stumps. Fruiting bodies of the fungus and dead stumps of diseased palms should be extracted along with major portion of roots and destroyed by burning (Venkatarayan, 1935; Venkatakrishnaiah, 1956). Improving the drainage condition of the soils, avoiding dense planting of palms and adoption of clean cultivation of gardens help in checking the disease. Planting of susceptible trees such as *Delonix regia, Pongamia glabra, Cassia siamea* etc. in the vicinity of gardens should be avoided. When once the disease appears, its spread to neighbouring palms could be prevented by digging deep trenches all around the affected palm (Anonymous, 1956b).

4. Inflorescence die–back and button shedding

Die–back of inflorescence due to the association of micro–organisms is reported to be associated with the low fruit set in arecanut (Anonymous, 1971). About 60% of the palms in the states of Karnataka and Kerala are infected by this disease causing severe shedding of buttons (Saraswathy, Reddy and Nair, 1977). No systematic survey has been conducted to assess the crop loss caused by this disease.

i. *Symptoms*

Disease appears first on the rachillae of the male flowers, then in the main rachis as brownish patches which soon spread from tip downwards covering the entire rachis causing its wilting. The female flowers of the infected rachis are shed (Fig. 7.6B). The fungus also infects the developing embryo inside the female flowers, which eventually shrivels up showing a brown discolouration. Under severe condition the fungal infection proceeds from tip downwards producing the condition known as die–back (Rao, 1965). Concentric rings of light pink coloured conidial mass of the pathogen appear on the discoloured portions

of the infected inflorescence (Anonymous, 1961). On closer examination, a tuft of mycelial growth of the fungus could be observed on the stigmatic end of the fallen buttons. The disease is present throughout the year, but is most serious during the dry period (February–May).

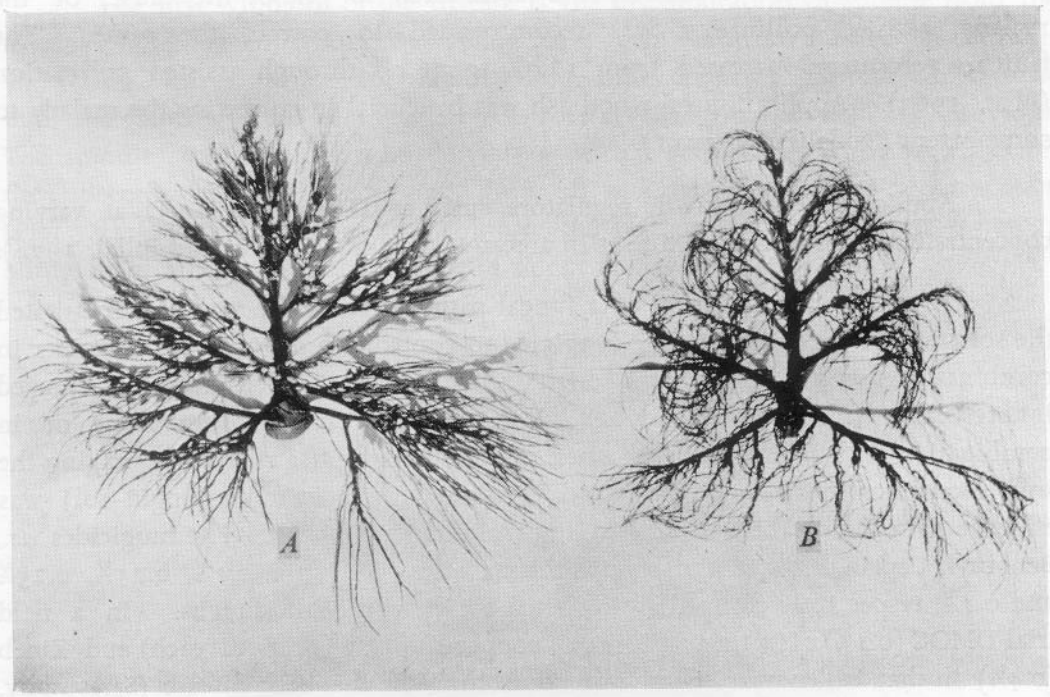

Fig. 7.6 Inflorescence die-back. *A. Healthy inflorescence. B. Inflorescence showing die-back with shrivelled female flowers.*

ii. *Etiology*

Nutritional and physiological factors are reported to be the possible causes of drying of arecanut inflorescence and shedding of buttons. Raghavan and Baruah (1956) were of the view that the shedding of female flowers is due to lack of pollination and fertilisation.

The fungus *Gloeosporium* sp. was associated with the fallen nuts and infected inflorescence (Anonymous, 1938b). The toxin produced by the fungus was considered responsible for the pathological conditions (Menon, 1961b). Saraswathy et al., (1977) could invariably isolate the fungus *Colletotrichum gloeosporioides* Penz. the conidial state of *Glomerella cingulata* (Ston.) Spauld and Shrenk, both from the

fallen buttons and infected inflorescence. The primary pathogenic nature of the fungus was confirmed through inoculation experiments by the production of characteristic symptoms of the disease causing heavy shedding of female flowers.

iii. *Control*

Since lack of pollination was considered as one of the causes of the malady, assisted pollination was recommended to correct the same. The fruit set percentage increased from 12.0% to 26.4% through assisted pollination (Bhat, 1963). Application of wood ash was beneficial in correcting the malady to some extent (Saidalikutty, 1951).

Application of growth regulators such as GA and 2, 4–D at varying concentrations increases the fruit set in arecanut (Yadava, Murthy and Pillai, 1974).

The constant association of a fungal pathogen with the malady necessitated the selection of the most effective fungicide to control the disease. Shell copper in combination with Endrex gave high retention of tender nuts in sprayed inflorescences (Anonymous, 1960a), while 1% Bordeaux mixture alone or in combination with Endrex gave the same result (Anonymous, 1963a). Spraying the inflorescence with Dithane Z–78 and Heptane antibiotic (aureofungin–sol) was effective in reducing the button shedding (Anonymous, 1971). The fungicides *viz.*, Benomyl, Captan, Thiram and phenyl mercury urea *in vitro* at 0.1%, 0.25%, 0.25% and 0.1%, respectively completely inhibited the growth of the fungus. In a field trial DMOC (0.1%), Heptane antibiotic + copper sulphate (50 ppm each) and Zineb (0.4%) in that order were effective in controlling the die–back disease (Saraswathy, Reddy and Nair, 1975).

For controlling this disease, one spraying at the time of opening of female flowers and the second after an interval of 20–25 days are recommended. Removal and burning of infected inflorescences reduce the inoculum and consequently reduce further incidence of the disease.

5. Bud rot

During the course of investigations on *mahali,* Coleman (1910) observed that the same pathogen also affects the spindle of the areca palm causing rotting of the growing bud, which eventually kills the palm. The disease was recorded in a severe form in the heavy rainfall tracts of Karnataka by Nambiar (1949). Though the disease generally occurs in monsoon season, the fresh infection during November onwards becomes severe during succeeding months (Marudarajan, 1950b).

An annual crop loss of 1 per sent or more was recorded by Coleman (1910). However heavy crop loss due to the bud rot disease in endemic areas was also reported (Dorasami, 1956).

i. *Symptoms*

The first symptom of the disease is the discolouration of spindle from the natural light green colour to yellow and then brown. Infection spreads to young leaves which rot rapidly. As the infection spreads inside the bud, the growing point of the stem also rots resulting in the death of the palm. The spindle slumps and can be drawn out with a gentle pull. The outer leaves then become yellow, droop and drop off one by one leaving a bare stem (Fig. 7.7). Secondary organisms colonise the rotting bud and convert it into a slimy mass which would emit a foetid odour (Coleman, 1910).

Fig. 7.7 Bud rot affected crown

ii. *Etiology*

The fungus *Phytophthora arecae* causing the *mahali* disease may pass on to the growing bud from the infected bunches and cause the bud rot. Independent infection of leaf sheaths surrounding the growing point by the pathogen has also been suggested (Coleman, 1910). Rao (1962b) observed rotting of areca spindles from tip downwards caused by *Gloeosporium* sp. A crown rot disease has been observed in a serious form in Assam areas where constant association of fungus *Thielaviopsis paradoxa* was observed (Anonymous, 1970; Sarma and Murthy, 1971).

Naidu and Kumar (1964) recorded *Nigrospora sphaerica* causing severe rotting of young leaves which allows entry of other bud rotting fungi resulting in the death of the palms.

Occurrence of a bacterial rot on spindles of young areca palms was noticed by Naidu (1960) in many areas of Karnataka, characterised by discolouration and drying of heart–leaf from tip downwards. Lightning injury also causes rotting of the bud in areca palms.

iii. *Control*

Infected tissues of bud is to be scooped off and treated with 10% Bordeaux paste. Destruction and removal of dead palms and also bunches affected by *mahali* and drenching crowns of surrounding healthy palms with 1% Bordeaux mixture would help in minimising the incidence of bud rot disease (Nambiar, 1956; Anonymous, 1960a). Drenching the crown with mercuric compounds like 0.2% Ceresan wet or Leytosol helps to bring down the bacterial infection of the crown (Naidu, 1960). Since high humidity and over–crowding predispose the palms to infection, close planting in low lying areas and dense intercropping should be avoided.

6. Bacterial leaf stripe disease

The first report of a bacterial disease on arecanut is that of Orian (1939) who observed natural infection of arecanut by *Xanthomonas vasculorum* (Cobb) Dowson, the incitant of gumming disease in sugarcane. Rao and Mohan (1970) reported the occurrence of the bacterial leaf stripe on arecanut in Tumkur areas of Karnataka state in an endemic form.

i. *Symptoms*

The initial characteristic symptoms of the disease are 1–4 mm wide, dark green water soaked, translucent, linear lesions or stripes alongside and parallel to

the midrib of the leaflet or its other main veins. The lesions may develop at any point on the lamina, but more commonly from the base or towards the tip of the leaflet. The margin of the lesions are usually straight and well–defined, but occasionally it may appear wavy. The lesions are covered with abundant bacterial exudates on the lower surface. The exudate is creamy white and slimy. On drying, it forms a waxy film or creamy white to yellowish flakes or fine granules or irregular yellowish masses. In the advanced stages, the lesions may measure 1 cm or more wide and several centimeters long involving the midrib also. The affected midrib and veins of the leaflet get discoloured and turn black. All the leaflets of a leaf may be affected resulting in complete or partial blighting of the leaf and in severe cases the entire crown may be killed particularly in seedlings (Rao and Mohan, 1970; Kumar, 1981).

ii. *Etiology*

Microscopic examination of the affected leaf tissue shows profuse bacterial streaming throughout the surface of the cut end indicating the parenchymatous nature of the disease (Rao and Mohan, 1970). The organism was isolated in pure culture. On the basis of its cultural and morphological characters, the pathogen was identified as *Xanthomonas arecae* (Rao and Mohan, 1976). The pathogen produced typical symptoms on artificial inoculation on arecanut (Rao and Mohan, 1970; Anonymous 1976). The bacterium caused the development of dark green, water soaked elongated lesions on coconut and other ornamental palms.

The causal bacterium produces large quantities of extra–cellular toxic polysaccharides. The ability to form polysaccharides in phytopathogenic bacteria has been linked to the virulence of the pathogen. In highly susceptible arecanut cultivars, the proliferation of the pathogen results in copious amounts of gum production, chlorosis, localised water soaking and invasion of host cell. The purified extra–cellular polysaccharide produced characteristic symptoms in detached arecanut leaves. The toxin is a heteropolymer of glucose, galactose, mannose and small amount of glucuronic acid (Kumar, 1981).

Most of the phenolic acids were common to both diseased and healthy leaf tissues of arecanut. The diseased leaf tissues contained an extra phenolic acid formed as a result of host pathogen interaction (Kumar, 1981).

iii. *Epidemiology*

The disease remains aggressive during and after the rainy season and it is of little significance during the hot dry summer months. Kumar (1981) obtained

a strong correlation between mean temperature and disease incidence and also observed that the incidence was high during the months of July to October when the average monthly rainfall is 130 mm or more with more than 10 rainy days per month. The organism does not survive in soil for long, indicating that soil may not be a primary source of inoculation.

Three to five year–old palms are highly susceptible to the disease than older palms (Kumar, 1981).

iv. *Control*

Antibiotics like tetracycline and its formulations are effective as prophylactic and curative treatments at 500 ppm concentration. Stem injection of antibiotics has longer residual effect than foliar spray (Kumar, 1981).

7. The *band* or *hidimundige*

The name *band* is given to peculiar diseased condition of arecanut palm reported as a major problem along the Konkan coasts in Maharashtra. The term *band* means barren in Marathi language, as the diseased palm ceases to produce fruits. In Karnataka, the disease is known as *hidimundige*. A similar disease was reported from Sri Lanka known as 'pencil point' and from Australia as 'rosette' disease. According to Joshi and Joshi (1952), the malady was prevalent in Bombay areas even before the year 1889. The disease causes gradual but considerable monetary loss to the growers. Coleman and Rao (1918) attributed the disease to adverse environmental factors.

i. *Crop loss*

Crop loss due to this disease varies from 5 to 25% or more according to locality and time of observation (Joshi and Joshi, 1952). About 50% of the palms in Kolaba and Ratnagiri districts of the Maharashtra are affected by this disease. In general, the plantations on the plains are affected more than those on hill tops (Kibe, Gokhale and Narayana, 1956).

ii. *Symptoms*

The production of smaller leaves is the first symptom. The leaves become dark green in colour, smaller in size and ultimately the crown forms a rosette shape. The leaflets are brittle with wavy margins. The leaves which instead of opening out, in due course tend to remain closely packed round the stem tightly binding the top portion of the palm (Fig. 7.8). This prevents the normal development of the growing point. Sometimes small multiple shoots emerge due to the arrest of normal growth of bud due to the presence of persistent leaf bases of lower leaves.

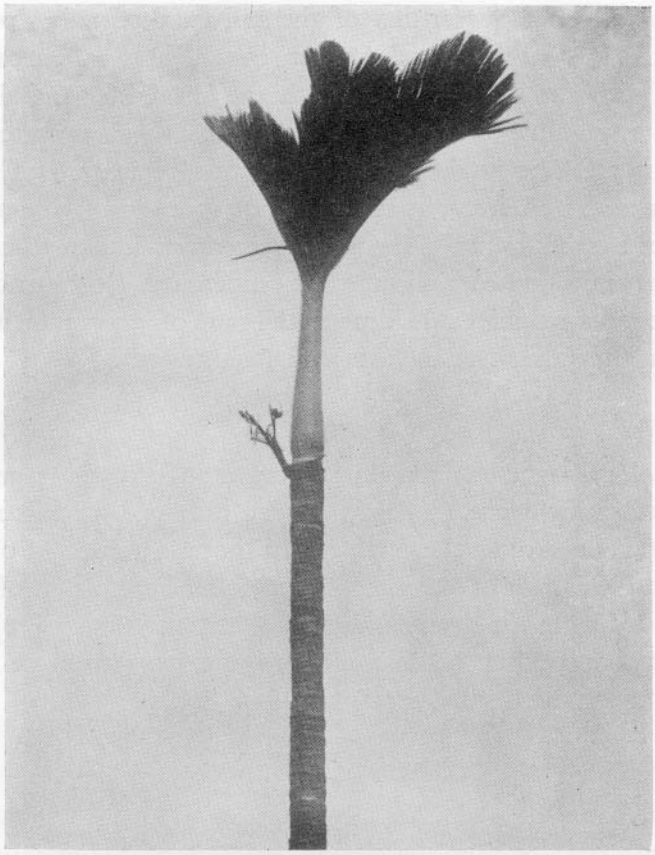

Fig. 7.8 Crown of *band* affected palm

The reduction in internodal length and tapering of the stem towards apex have also been recorded (Patel and Rao, 1958). The affected palms remain mostly unproductive and continue to live for years. The nuts if at all produced are small and malformed. Roots are poorly developed, short, brittle and crinkled.

iii. *Etiology*

The cause of the disease however, is not yet known. No biotic agent is found to be associated with the disease and it does not seem to be contageous. The attribution of this disease to the nematode *(Aphelenchus coccophilus)* infestation (Thirumalachar, 1946) was refuted by Venkatarayan (1946). It has not been possible to transmit the disease from one palm to another (Nayar, 1976).

Poor drainage and low fertility of the soil are reported as possible causes of the disease (Gokhale, Kasaragode and Ajrekar, 1916). Lateritic subsoil pan or hard clayey pan are found to be associated with the disease. Imbalanced nutrition of the palms as a possible cause of the disease has been reported, (Daji, 1948; Joshi and Joshi 1952; Kibe et al., 1956). Comparative analysis of soil samples of healthy and disease affected arecanut areas did not show any significant difference in the contents of major nutrients. The zinc content was low in diseased soils while boron and manganese contents showed no difference (Joshi and Joshi, 1952). Application of copper sulphate and lime at the rate of 30 gm each per palm was effective in controlling the disease (Joshi and Joshi, 1952).

iv. *Control*

Better soil management and improvement of the drainage were found to minimise the disease incidence. Palms in well managed gardens responded more to manurial treatments against the disease than those in neglected ones (Kibe et al., 1956). Removing hard pan of the subsoil and foliar application of micronutrients were effective in reducing the disease intensity (Patel and Rao, 1958). Correction of soil acidity and incorporation of a mixture of copper sulphate and lime to the basal soil could check the disease effectively (Rao, 1960).

8. Sun scorch (Stem breaking)

In many parts of Dakshina Kannada district, the areca growers were reporting breakage of stems in the upper half during heavy winds. A small research unit was established at Vittal, Dakshina Kannada in 1952 with the objective of investigating the factors leading to the incidence of stem breaking disease and to evolve suitable control measures. Detailed observation of the disease in relation to nature of soil, manurial practices, exposure to sun, drainage etc. were made and various prophylactic measures were suggested (Anonymous, 1956a) based on the work carried out under the scheme.

i. *Symptoms*

The initial symptom appears as golden yellow patches on the stem against green background of young stem facing the south west sun. These patches later turn dark brown followed by development of longitudinal cracks of 1–3 cm deep all along the length of stem. The palms standing in the southern and northern borders are severely affected on account of direct exposure to the sun. Saprophytes which harbour the scorched tissue accelerate damage to the stem and the monsoon winds finally break such affected stem (Fig. 7.9).

Fig. 7.9 Stem breaking

ii. *Etiology*

Coleman and Rao (1918) felt that the cracking of arecanut stem was due to exposure to the sun. A number of fungi *viz., Ceratostomella paradoxa, Lenzitus* sp., *Acrothecium* sp., *Polyporus* sp., *Ganoderma lucidum, Polystietus* sp., *Nigrospora* sp., *Pestalotia palmarum* and *Fusarium* sp. were isolated from the affected tissues. Of these, *C. paradoxa, Lenzitus* sp., *G. lucidum* and *Polyporus* sp. could cause infection of stems of young palms when inoculated through wounds caused by sun scorch (Coleman and Rao, 1918; Patel and Rao, 1958). Continued scorching followed by fungal infection weaken the stem and cause its breaking during strong winds (Seshadri and Rawther, 1968). The side of the stem subjected to wide fluctuations in temperature is more prone to sun scorch.

iii. *Control*

Stem breaking can be reduced by trailing pepper vines along the stem, raising rapidly growing trees on the southern and western sides of the gardens (Kurup, 1955) and by protecting the trunk with a cover of dry leaves (Anonymous, 1956a). Reinforcing the cracked portions with split areca stem renders mechanical support to the weak trunk (Anonymous, 1956a). To minimise the incidence of this malady a suitable alignment of the planting was suggested by Bhat (1965).

9. Stem bleeding

Nambiar (1949, 1951) reported the occurrence of stem bleeding disease in isolated pockets of Mettupalayam areas in Tamil Nadu. The disease is of rare occurrence in South India and closely resembles the stem bleeding disease of coconut (Anonymous, 1953b; Sundararaman, Nair and Ramakrishnan, 1928). Though both young and older palms are affected, the young palms are more susceptible (Patel and Rao, 1958).

i. *Symptoms*

Symptoms appear on the basal portions of the stem as small discoloured depressions during initial stages. Later these spots coalesce and cracks develop on the stem. With the progress of the disease, the fibrous layer disintegrates which eventually hollows upto varying depths along the infected portion. Crowns of affected adult palms get reduced in size followed by reduction in yield. Finally a dark brown liquid oozes out from the cracks (Sundararaman et al., 1928).

ii. *Etiology*

The fungus *Thielaviopsis paradoxa* is associated with the disease (Sundararaman et al., 1928).

iii. *Control*

Since the disease is serious in areas with poor drainage (Varadarajan, 1958), improving the drainage may help in minimising the disease incidence. Application of hot coaltar (Sundararaman et al., 1928; Nambiar, 1949) or Bordeaux paste (1:1:10) (Patel and Rao, 1958; Seshadri and Rawther, 1968) is effective in reducing the disease incidence.

10. Nut splitting

This is considered to be a physiological disorder rather than a pathological disease. Nambiar (1949) reported nut splitting characterised by the

cracking of fruits known as *anduadakke roga* in Karnataka. The disease is known as *achikeeral* in Ponnani in Kerala. This abnormality is seen in patches in individual gardens and are common in young palms.

i. *Symptoms*

Symptoms appear as premature yellowing of the nuts where they are half to three fourth mature. This is followed by cracks at the tips which extend longitudinally towards the calyx exposing the kernel (Fig. 7.10). Kernel also exhibits cracking and as a result becomes malformed. Splitting may begin at the calyx end also proceeding half–way to the apex or the cracking may be restricted to only one end of the nut (Bhat, 1961). All the nuts in a bunch may succumb to the disease. It is also not uncommon to see tender nuts with informal splitting in the husk without showing any sign of external fissures, resulting in nut fall. The disease may occur in the same palm year after year. Palms at the age group of 12–25 years are more susceptible.

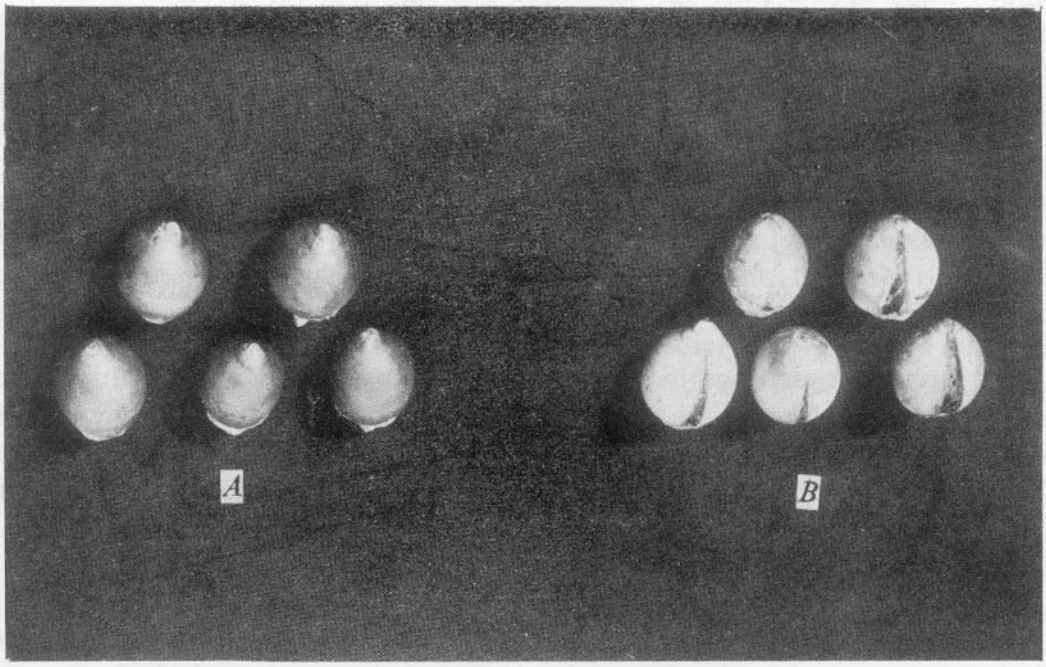

Fig. 7.10 Nuts splitting. *A. Healthy nuts. B. Damaged nuts.*

ii. *Etiology*

The possible causes suggested are hyper nutrition or sudden flush of water after a period of drought or insufficient moisture which upsets the rhythm of development of pericarp and the tissue inside. According to Bhat (1961) application of potash could reduce nut splitting indicating potassium deficiency.

iii. *Control*

The splitting can be reduced by making longitudinal side slits at the base of inflorescence (Bavappa and Sahadevan, 1952; Patel and Rao, 1958). Improving the drainage in gardens having water stagnations or ill-drained conditions may help to minimise the disease incidence. Spraying borax @ 2g per litre of water on the bunches during early stage of disease incidence and application of potash at the base reduce splitting.

II. Diseases affecting the seedlings

1. Yellow leaf spot

Seedlings (1–2½ year old) exposed to the sun are susceptible to this disease (Anonymous, 1961; Rao, 1962a). The disease is severe during summer months (February–March) and continues to infect seedlings until the onset of rains. Symptoms appear on the lamina of the leaf as yellow specks measuring 3–10 mm in diameter. These spots coalesce to form larger lesions surrounded by yellow haloes. Minute brown pin head like structures appear at the centre of the lesions. Infection leads to stunted growth and in severe cases death of the seedlings (Anonymous, 1953a). Menon (1962) isolated *Curvularia* sp. from the affected tissue. Fungi such as *Colletotrichum, Phyllosticta, Helminthosporium* (Rao and Bavappa, 1961) and *Alternaria tenuis* (Agnihotri, 1963) have also been reported to cause leaf spot resulting in stunted growth of seedlings.

Improving drainage in the nursery and main field and providing shade minimise the incidence of the disease. Application of heavy dose of manures and spraying with Dithane Z–78 or 1% Bordeaux mixture reduce the disease incidence (Menon, 1962; Rao, 1962a). Fungicides like Ziram, mercurised copper oxychlorides were also found to be effective in checking the spread of the disease.

2. Leaf blight

The disease is characterised by reddish brown discoloured spots that blight the lamina. Poor soil fertility favours the incidence. Menon, Nair and Abraham, 1962 suggested application of nitrogen and potash to the plants followed by spraying

with Dithane Z–78 to check the disease. The fungus *Pestalotia palmarum* Cooke has been associated with the blight. Roy (1965) reported *Phomopsis palmicola* (Wint) Sacc. *arecae* as the causal organism of leaf blight in seedlings at the transplanting stage. This also leads to stunted growth.

Menon (1959b) reported a seedling blight caused by a pycnidial fungus and suggested shading and spraying with copper fungicides.

3. Red rust

This disease is caused by an algal parasite, *Cephaleuros* sp. which infects the stem and foliage. Circular spots with sunken centres and yellow haloes appear on the foliage. Lesions are irregular on the stem. Infection destroys the epidermis (Paily and Menon, 1960). This alga can be controlled by providing good shade and spraying with Bordeaux mixture (Westcott, 1966).

4. Root/collar rot

This is usually seen in nurseries with poor drainage. The rotting is caused by fungi like *Fusarium* sp. and *Rhizoctonia* sp. (Rao and Bavappa, 1961). The fungi infect roots and cause wilting of seedlings. Sometimes bacteria enter the stem through collar region and cause rotting of bud also. The severity of the disease can be minimised by providing good drainage in the nursery and drenching the soil with Ceresan wet or Bordeaux mixture or cheshunt compound.

III. Post harvest deterioration of arecanut

1. Nature of damage

Lack of proper drying yard, improper spreading and turning of nuts and exposure to unexpected rains during drying period lead to microbial infestation of husk as well as kernel. The infection affects the quality of nuts, renders it unsuitable for consumption and lowers their market value.

The invading fungi first attack the embryo and then spread to the central white core (Jaleel and Govindarajan, 1969; Nambiar, Edison and Nair, 1971). In advanced stages of infection the kernel will present a hollow cavity due to complete disintegration of the tissue by the invading fungi (Fig. 7.11). The affected nuts when cut open, show discoloured tissues of the white core, the colour being dependent on the fungi involved (Nambiar et al., 1971).

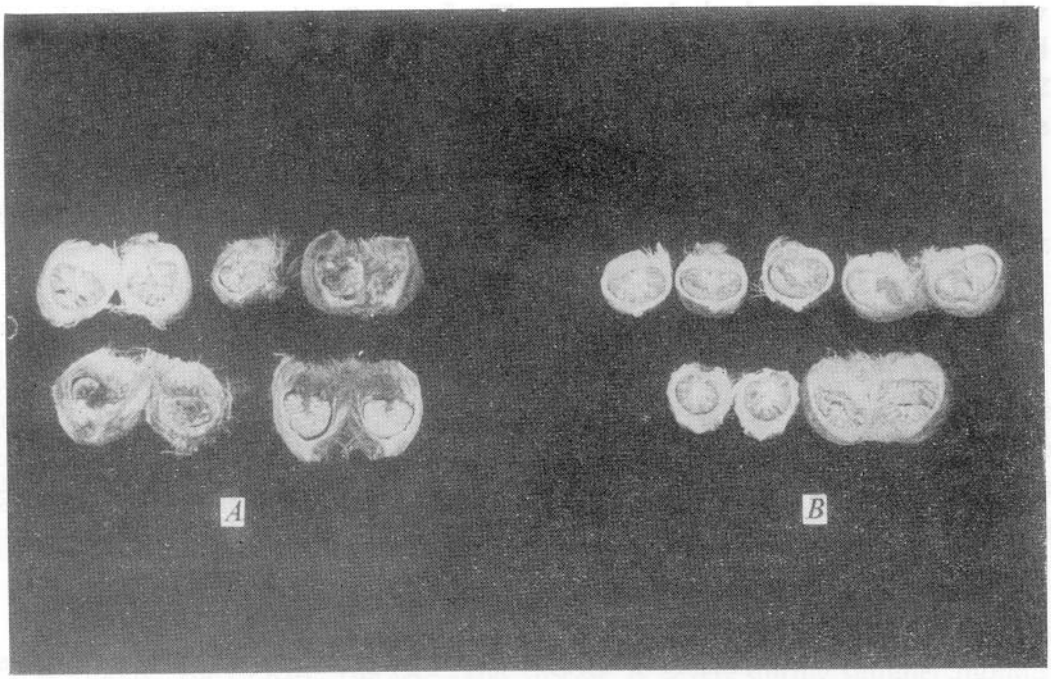

Fig. 7.11 Fungal infection of stored nuts. *A. Infected nuts. B. Healthy nuts.*

2. Loss

The extent of damage due to fungi and other biological agents aiding deterioration depends upon the nature and season of drying. When nuts are stored for one year, the infection increased from 33.7% to 60.7% (Anonymous, 1971). The infection of the kernel will be either mild, moderate or severe according to the duration of storage and fungi involved. Nambiar et al., (1971) found that the percentage of fungal infection was the highest in nuts dried in October (62%) and the lowest in February (21%).

3. Factors associated with deterioration

The increased fungal infection during October is attributed to the prevailing low temperature coupled with rains (157 mm) and consequent high relative humidity (upto 92%) which are congenial for the growth of fungi. The nuts also do not dry quickly under such conditions. The low percentage of infection in February is due to higher temperature and low relative humidity (Table 7.4; Nambiar et al., 1971).

Table 7.4. *Mean percentage of fungal infection in processed arecanuts during different months*

Months	Infection (%)	Range of temperature		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
October, 1969	61.5	26.0–35.0	19.1–22.3	56.8–92.4	156.8
November, 1969	52.8	31.0–34.5	15.4–22.6	46.9–87.7	454.4
December, 1969	43.8	31.0–35.0	12.7–22.9	49.6–86.8	0.0
January, 1970	31.5	31.4–35.8	14.9–18.6	33.2–85.7	0.0
February, 1970	21.0	32.5–36.5	16.0–20.9	48.1–91.9	0.0
March, 1970	25.7	33.8–37.8	19.1–24.1	50.7–90.2	1.2

Studies on the extent of infection during different stages of drying showed that majority of infection in nuts occurred during the first 5–10 days, presumably from husk. The slow drying of endosperm coupled with its high nutrient content encourage the fungi to penetrate inside and attack the kernel (Nambiar et al., 1971).

4. Fungi associated with deterioration

A normal and unblemished areca fruit is generally considered to be free from any incipient fungal infection. Moreover, when the nuts were harvested by eliminating soil contact and dried in hot air oven at 65°C for 63 hr the kernel was found free of fungal infection. On the other hand, when the harvested bunches and nuts were collected from the ground and the nuts dried in the sun, the infection was about 60 per cent indicating that fungal infection is from the soil either during harvesting or during drying (Nambiar and Nair, 1970).

Usually the microflora associated with the husk and kernel are *Aspergillus* sp., *Diplodia* sp., *Fusarium* sp., *Mucor* sp., *Penicillium* sp., *Thielaviopsis* sp. and certain aerobic bacteria (Anonymous, 1961, 1962), *Cladosporium* sp. (Anonymous, 1970), *Phomopsis heteronema* (Butler and Bisby, 1931) and *Colletotrichum gloeosporioides* (Saraswathy et al., 1977). The fungi found in stored arecanuts are *A. niger arecae* (Lal and Chandra, 1953), *Subramanella arecae* (Srivastava, Banu and Govindarajan, 1962) and *A. chevalieri* (Anonymous, 1971). Fungi associated with spoilage of dried arecanuts with their relative intensities are given in Table 7.5 (Nambiar et al., 1971).

Fungal infection of stored nut was maximum in 'Sweet areca' among different cultivars probably due to the larger endosperm which is a good substratum to the fungi (Anonymous, 1971).

Table 7.5. *Fungi involved in the spoilage of stored arecanuts*

Fungi	Colour of infected kernel	Infection percentage
Aspergillus niger	Black	6.4
A. chevalieri	Yellow	
A. flavus	Yellowish green	
A. fumigatus	Velvetty green	
Penicillium sp.	Felty olive green	1.3
Botryodiplodia theobromae	Grey to greyish black	19.3
Rhizopus sp.	Grey	1.8
Mucor sp.	Yellowish grey	0.7
Thielaviopsis paradoxa	Black	0.2
Total		29.7

5. Control

Elimination of soil contact by the harvested nuts is beneficial in reducing nut infection since it is the prime source of infection. Harvested nuts treated with Blitox showed less infection (Anonymous, 1962). Steeping the nuts in Bordeaux mixture followed by drying in cement floor reduced the percentage of infection significantly. When nuts were harvested without soil contact and dried in hot air oven at 65.0°C for 63 hr, there was no infection (Nambiar et al., 1971). Nuts harvested by the conventional method and dried in mechanical drier (Nambudiri, Govindarajan and Subramanian, 1963) at 62°C for 72 hr contracted 3.6 per cent infection (Nambiar et al., 1971). Nuts dried on cement floor had only 5 per cent fungal infection and the time required for drying was also less in this case (Anonymous, 1972). Polythene lined gunny bags can be used with advantage over plain gunny bags for storing nuts (Nambiar et al., 1971). Arecanuts stored in air-tight bins had only 17.7 per cent infection as against 32.3 per cent infection in nuts stored in gunny bags. Storing nuts in polythene lined gunny bags also reduces fungal infection (Nambiar et al., 1971)

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8

CHEMICAL COMPOSITION AND PROCESSING

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Arecanut, to most of the Orientals, and specially to Indians, is as dear as chewing gum for the Americans. The nut is used in raw or processed form. Depending upon the nature of end products, the fruit is harvested at different stages of maturity for processing. It is seen that the fruits and nuts vary in size, shape, texture and taste.

I. Chemical composition

The chemical composition of marketed arecanuts depends on the maturity of the nut since processed arecanuts are made from both green and ripe nuts (Table 8.1) (Sivasankar, Mathew and Natarajan, 1976). The major constituents are polyphenols, fat, polysaccharides, fibre and protein. Alkaloid is present as a minor but significant constituent. The mineral matter contains calcium (0.05%) phosphorus (0.13%) and iron (1.5 mg/100 g) (Anonymous, 1948).

Table 8.1. *Range of variations of the chemical constituents of green and ripe arecanuts*

Constituents*	Green nut (*Kalipak* stage)	Ripe nut
Moisture content	69.4–74.1	38.9–56.7
Total water extractives	32.9–56.5	23.3–29.9
Polyphenols	17.2–29.8	11.1–17.8
Arecoline (extraction method)	0.11–0.14	0.12–0.24
Fat	8.1–12.0	9.5–15.1
Crude fibre	8.2–9.8	11.4–15.4
Total polysaccharides	17.3–23.0	17.8–25.7
Crude protein	6.7–9.4	6.2–7.5
Ash	1.2–2.5	1.1–1.5

* Constituents expressed as percentage values calculated as dry basis (except moisture)

Polyphenols, which are the major components, constitute about 20 per cent of the dried arecanut. They have been identified to be flavonols. The monomeric components include about 10 per cent of (+) catechin, 2.5 per cent epicatechin, 12 per cent of (+) leucocyanidin and 1.3 per cent of another isomer of leucocyanidin, out of the total polyphenols. The remaining are made up of complex flavonoids in varying degrees of polymerisation. (+) Catechin was studied and isolated by earlier workers (Anonymous, 1961a). Leucocyanidin has been isolated and identified by means of its derivatives and its physical properties (Nagarajan and Seshadri, 1961; Banerjee, Rajadurai and Nayudamma, 1961). By acid hydrolysis and study of the reaction products, they are found to have predominantly, leucocyanidin and traces of catechin and leucopelargonidin (Govindarajan and Mathew, 1963; Mathew, Parpia and Govindarajan, 1969).

There are a few alkaloids present in arecanut and arecoline ($C_6H_{11}O_2N$) is the most important among them. Others are arecaidine ($C_7H_{11}O_2N$), guvacoline ($C_7H_{11}O_2N$), guvacine ($C_6H_9O_2N$) etc. According to Continental Pharmacopoeias the seeds should contain not less than 0.4 per cent of alkaloids, calculated as arecoline. The arecoline content is found to vary from 0.10 to 0.67 per cent (Anonymous, 1948; Raghavan and Baruah, 1958; Dutta and Dutta, 1959).

The alkaloids of arecanut in general are all derivatives of tetrahydronicotinic acid. Arecoline which is the most important alkaloid in the product, is known to act on the central and peripheral nervous system and produce paralysis, preceded by convulsions. However, its hydrobromide is recognised by some pharmacopoeias and used in veterinary preparations as a vermifuge (Anonymous, 1948; Sivasankar et al., 1976).

The percentage of fat in dry, ripe arecanut ranges normally between 9 and 15. A sample of arecanut fat showed a melting point of 38°C, specific gravity of 0.973 at 15°C and a saponification value of 236.4. Mathew et al., (1974) reported an iodine value of 59.0. A few other workers reported a lower value (Pathak and Mathur, 1954; Rajagopal and Achaya, 1961; Kartha, Sethi and Narayan, 1959). Jamieson (1943) reported as low as 12.3 for iodine value. It is rich in saturated lower fatty acids, especially myristic acid and to a lesser extent, lauric acid (Pathak and Mathur, 1954; Rajagopal and Achaya, 1961) and resembles *vanaspati* in melting point, consistency and appearance. The fat showed no external flavour resembling arecanut in raw form and on frying (Mathew et al., 1974).

1. Changes in chemical composition with maturity

Changes in the chemical characteristics of the nuts with maturity of different varieties have been studied by Mathew, Venkataramu and Govindarajan, (1964). It is observed that two months old tender arecanut offers no resistance while cutting. At about four to five months, the outer skin is dark green and inside it is translucent and jelly-like, with the pale coloured streaks making their appearance. Six to seven months old green nut is comparatively hard, but can be cut easily. It has more or less a white core and light brown veins from periphery to core. This stage is ideal for making the processed *kalipak* or *kaliadeke* of South India. At about nine months maturity, the ripe fruit has a yellow to orange red colour; the enclosed hard nut has distinct brown polyphenol veins enmeshing white fat, polysaccharides and the white core. Such nuts are used in raw form or after drying as *chali supari.*

The chemical composition of arecanut at different stages of maturity is given in Table 8.2 (Mathew et al., 1964). The total water extractives constitute about 75 per cent in tender stage and drop down to 20–30 per cent when ripe. At different stages of maturity, the polyphenols form more than 50 per cent of total water extractives. Polyphenols on dry nut basis decrease with increasing maturity of the fruit. Probably large concentration of polyphenols at the tender stages of growth, affords better protection to the nut from infection. With maturation, the rapid formation of polysaccharides, fat and fibre, increases the bulk of the nut diluting the total polyphenolic content. The polyphenols of arecanut at all the stages have been found to be flavonoids. The pattern of changes with maturation and ripening is found to be due to insolubilization of higher polymers together with formation of fresh monomers and intermediate polymers (Mathew and Govindarajan, 1964).

In the earlier studies conducted by Mathew et al., (1964), the arecoline was estimated making use of the extraction method (Mukherji, 1955), according to which the ripe arecanuts had a higher arecoline content of 0.2 – 0.3 per cent compared to tender nuts with 0.05 – 0.1 per cent. However, in the subsequent studies by distillation method (Nambudiri, 1968) the *kalipaks* made from tender nuts had a higher arecoline content than ripe nuts. This must be probably due to the fact that in tender stages, arecoline may be in a complexed state, from which it is difficult to release by ordinary extraction technique.

Changes in fat, polysaccharides and fibre have also been studied. Generally the fat increases from 1 to 4 per cent in tender stages to a level of 10–15 per cent

in ripe nuts. The free fatty acid content decreases with maturity indicating the use of it for biosynthesis of the fat. The increase in fat content with maturity has been reported by many workers (Raghavan, 1957; Kartha et al., 1959). In a few cases, the fat increases upto mature green stage, and then decreases (Banerjee et al., 1961; Mathew et al., 1964).

Table 8.2. *Composition of arecanut ('South Kanara' type) at different maturity stages (values except moisture are expressed on dry basis)*

Composition	Stage of maturity of nuts				
	Very tender	Tender	Mature green	Semi-ripe	Ripe
Average weight of fruit (wet, g.)	4.71	11.97	26.40	35.16	35.05
Moisture content of husk (%)	91.68	70.78	79.77	75.46	74.70
Average weight of husk (dry, g.)	0.22	2.43	3.38	5.25	5.40
Average percentage of husk (on total dry weight)	75.86	80.72	54.25	43.08	39.40
Moisture content of nut (%)	88.34	84.00	70.60	49.52	39.40
Average weight of nut (dry, g.)	0.07	0.58	2.85	6.94	8.31
Average percentage of nut (on total dry weight)	24.14	19.28	45.75	56.92	60.60
Total water extractives (%)	65.60	73.72	56.49	34.80	27.89
Polyphenols (tannins, %)	43.85	47.94	29.44	26.40	17.81
Alkaloid (as arecoline, %)	Nil	0.06	0.14	0.20	0.22
Fat (%)	1.22	5.02	8.08	13.74	14.29
FFA (as oleic acid-% on fat)	1.40	2.13	0.88	0.65	0.45
Crude fibre (%)	1.97	6.32	8.23	10.75	13.42
Total polysaccharides (hydrolysable, %)	4.68	13.50	17.58	21.26	23.57
Nitrogen (%)	2.67	1.60	1.51	1.36	1.20
Ash (%)	3.77	3.31	2.52	1.71	1.50
Water soluble ash (%)	1.98	1.72	1.46	1.02	0.91
Water insoluble ash (%)	1.79	1.59	1.16	0.69	0.59
Alkalinity of soluble ash (ml. of N HCl/100 g)	4.00	3.50	2.52	2.75	2.50
Acid insoluble ash (%)	0.15	0.08	0.05	Nil	Nil

Kartha et al., (1959) showed that major amount of fat was developed during the last phase of maturity. Pathak and Mathur (1954) have studied the glyceride structure which agrees well with the *rule of even distribution.* Studies on fatty acid composite have revealed that the fat is rich in myristic acid and lauric acid (Rathje, 1908; Pathak and Mathur, 1954; Rajagopal and Achaya, 1961).

The hydrolysable polysaccharides increase from about 5 per cent in tender stage to a level of 25 per cent in ripe stage (Mathew et al., 1964). In earlier

literature, higher values have been reported (Waheedkhan and Ghughtai, 1956). This may be due to the fact that the values were obtained by difference and without accounting for the polyphenols present. Mathew et al., (1964) have reported the total hydrolysable polysaccharides estimating it after hydrolysis with normal hydrochloric acid at 100°C for $2\frac{1}{2}$ hr. The products of hydrolysis have been shown to be galactose, glucose, mannose, arabinose and xylose. Sucrose, glucose and fructose are the free sugars.

Crude fibre of the tender nut is found to be very low (about 1–2 per cent). It steadily increases to a value of 15 per cent in the case of ripe arecanut.

It is seen that the nitrogen concentration is high in the tender stage and diluted with the formation of other constituents. The crude protein ($N \times 6.25$) of a ripe arecanut is generally found to be 6–7.5 per cent (Anonymous, 1962). However, different values have also been reported (Anonymous, 1948; Waheedkhan and Ghughtai, 1956).

The mineral matter and both water-soluble and insoluble ash decrease with maturity (Mathew et al., 1964).

The overall pattern of chemical composition of the nut reveals that at tender stages, the total water extractives containing mainly polyphenols are high, as also the nitrogen and ash contents. Polysaccharides, fibre, fat and alkaloid are formed rapidly in the middle stages. The hardening of the nut coincides with the drop in moisture content and formation of polysaccharides. Lignification and a high degree of polymerisation of polyphenols also contribute to this (Mathew et al., 1964).

II. Processing aspects of arecanut

Fully ripe arecanut is very popular in areas of Kerala, Assam, West Bengal and coastal Karnataka. The users of raw nut in these regions practice crude methods of preservation. In Assam, fresh fruits, as such are preserved in thick layers of mud to elicit a moist chewing feel in the mouth when consumed. The product known as *bura tamul* is often infected with fungus. In Kerala, fresh fruits are generally stored by steeping in water. Discolouration of outer husk and foul smell result in this, due to bacterial attack. The inner core is practically well preserved. Such water preserved nuts, known as *neetadaka* are favourite of many chewers who ignore its mild off-flavour.

Mathew et al., (1963) made use of a mixture of metabisulphite and benzoate at acid pH to preserve fully ripe nuts. An initial heat blanching was given to inactivate any enzyme acting in the husk. The method consists of washing freshly harvested arecanuts in chlorinated water (100 ppm chlorine) for removing dirt and other extraneous matter. This is followed by blanching in 0.2 per cent calcium chloride solution, which ensures firmness of husk and a lesser amount of surface microbial load. The enzymes of the husk are also inactivated as a result of blanching. The fruits are then kept immersed in a steeping solution containing 0.1 per cent sodium benzoate and 0.2 per cent potassium metabisulphite acidified to a pH of 3.5–4.0 using hydrochloric acid. Chemical and physical analysis indicated that fruits can be stored in good condition for 10–12 months (Tables 8.3 and 8.4).

Table 8.3. *Composition* of nuts from areca fruits ('South Kanara' type) stored for 8–10 months*

Constituents	Conditions of storage					
	Fresh	Steeped in water at pH 4.0	Steeped in mixed preservative at pH 4.0	Steeped in 0.25% sodium benzoate at pH 4.0	Blanched and steeped in mixed preservative at pH 4.0	Blanched and steeped in 0.25% sodium benzoate at pH 4.0
Moisture	40.52	51.53	47.32	49.71	51.33	49.77
Total water extractives	24.74	19.38	21.46	20.08	19.96	18.34
Tannins	12.71	12.18	11.96	12.18	11.97	11.55
Alkaloids (as arecoline)	0.15	0.10	0.11	0.08	0.06	0.14
Fat	14.11	13.34	14.52	16.56	15.27	16.25
F. F. A. (as oleic acid – % on fat)	0.61	2.39	2.09	1.03	2.31	1.49
Crude fibre	15.69	15.57	14.81	14.53	13.85	13.90
Total polysaccharides (hydrolysable)	18.33	19.51	20.16	20.37	18.51	18.09
Nitrogen	1.89	1.14	1.25	1.22	1.15	1.08
Ash	1.54	1.05	1.48	1.33	1·01	1.21

* Values except moisture calculated on dry basis. Constituents expressed as per cent.

1. Dried ripe nuts

The most popular trade type of arecanut is the dried, whole nut, known as *chali* or *kottapak*. Ripe nuts (Fig. 8.1A) are dried in the sun for 35–40 days on dry level grounds. The dried nuts are dehusked and marketed as whole nuts. Depending on the size, there are various grades and preference in different regions.

Table 8.4. *Evaluation of areca fruits ('South Kanara' type) stored for 8–10 months*

Characteristics	Condition of storage				
	Steeped in water at acid pH	Steeped in 0.25% sodium benzoate at acid pH	Blanched & steeped in 0.25% sodium benzoate at acid pH	Steeped in mixed preservative at acid pH	Blanched & steeped in mixed preservative at acid pH
Colour and shine of skin	Dark brown and dull	Orange yellow and dull	Brownish yellow and dull	Orange yellow and dull	Bright orange yellow and good shine
Firmness of husk	Soft	Soft	Soft	Some soft and some firm	Firm
Smell of the fruit	Bad smell	Slight off-smell	Slight off-smell	No bad smell	Normal
Appearance of the fruit	Normal	Normal	Tannin veins darker and core slightly dry	No bad smell, tannin veins slightly darker	Normal, tannin veins slightly darker and core slightly dry
Taste and smell	Bad smell	Mild with slight off-smell	Mild with slight off-smell	Slightly bitter with mild astringency	Mild with no bad or off-smell
Acceptability	Unacceptable	Unacceptable	Unacceptable	Not very satisfactory – just acceptable	Acceptable
Sodium benzoate in the nut (ppm)	–	345	365	321	396
Sulphur dioxide in the nut (ppm)	–	–		32–166	70–172

The well known grades of *chali* (Fig. 8.1B) in decreasing order of sizes are *moti, srivardhan, jamnagar* and *jini*. The characteristics of a good *chali* product are, absence of immature nuts, surface cracking, husk sticking, fungus and insect attack and good cutting feel, inside structure and taste (Anonymous, 1961b; Anonymous, 1962; Dhanaraj, Sankaran and Mathew, 1970). Inadequate drying usually results in fungal infection and in a poor quality product. The main producing areas of *chali* are Kerala, Karnataka, Assam and Maharashtra. Countries like Bangladesh, Malaysia and Sri Lanka also produce such nuts.

To facilitate drying and dehusking, sometimes the fruits are cut longitudinally into two halves and sun dried for about 10 days. The kernels are scooped out and given a final drying (Shamanna, 1951). This type of product is known as *parcha* (Fig. 8.1C) and is produced mainly in Kerala and Karnataka.

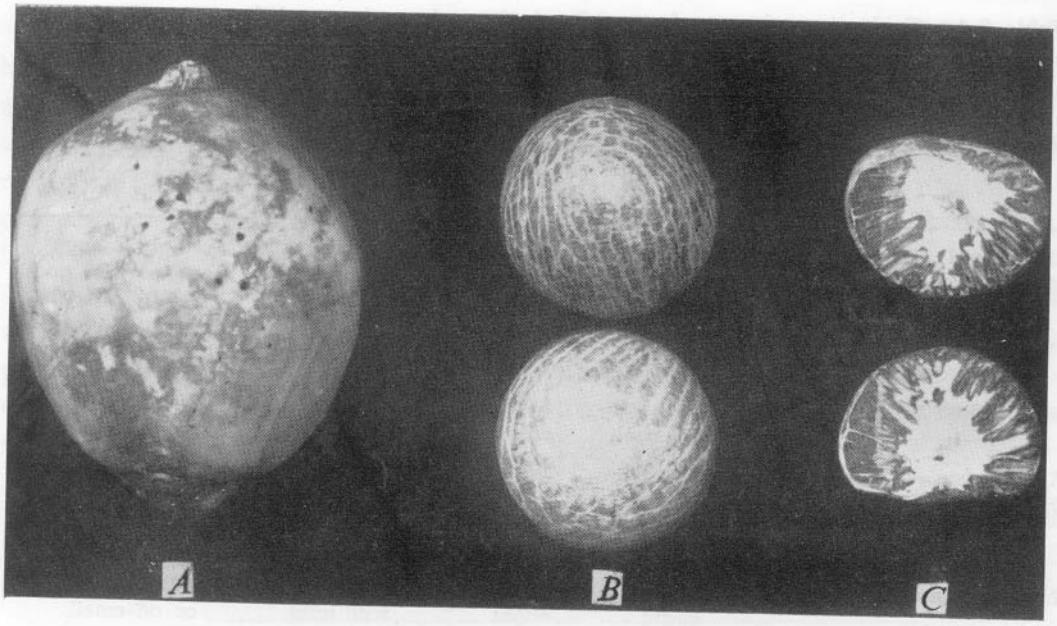


Fig. 8.1 A. Ripe nut. B. *Chali* or *Kottapak*. C. *Parcha*.

A mechanical through-flow drier has been recommended for making *chali* and *parcha* (Nambudiri, Govindarajan and Subramonian, 1963). In this type of drier, the hot air is allowed to penetrate through the bed of material kept in trays. The drier has a cabinet which is connected to a heat exchanger through a centrifugal blower. The bottom section of heat exchanger is connected to an oven and the top to a chimney. Drying will be completed in 60–70 hr over a period of 7–8 days at progressively increasing temperature between 45 and 70°C. The drying procedure consists of 8 hr consecutive drying followed by equilibration for 16 hr outside the drier. Table 8.5 gives a comparison of sun drying and mechanical drying.

Recently, a dehusking device to remove husk from dry arecanuts has been developed at CPCRI, Kasaragod (Bengali Baboo, 1980). The machine is operated by leg while feeding the nuts is done by hand simultaneously. The device loosens the husk of the nuts, which can be easily peeled off by hand. It is reported that an unskilled worker can make about 40 kg of *chali* in a day of 8 hr.

2. *Kalipak*

It is another important form of processed arecanut. Kerala and Karnataka are the main processing centres of *kalipak*. The nuts of 6–7 months maturity is

Table 8.5. *Data on drying of ripe arecanuts ('South Kanara' type)*

Batch	Condition of sample	Drying condition	Time of drying	Quality of nuts		
				Cracking (%)	Appearance	Moisture (%)
I	Good	50°C	56 hr	36.0	Light brown	10.2
	Good	80°C for 4 hr 50°C for 26 hr	30 hr	40.0	Dark brown skin	10.5
	Good	Sun drying	15 days	56.0	Brown skin	10.1
II	Damaged soft husk	60°C	30 days	50.0	Dark brown skin	8.9
	Damaged soft husk	90°C in a cross flow drier	27 hr	85.0	Black skin	8.8
III	Damaged soft husk	45°C	47 hr	58.0	Light brown skin	10.8
	Damaged soft husk	Sun-drying	15 days	54.0	Brown skin	11.5

soft and finger nail can be pressed into it. Outer skin is dark green in colour at this stage. The processing consists of dehusking, (Fig. 8.2) cutting the soft nuts into pieces (Fig. 8.3) boiling cut pieces with water or dilute extract from a previous boiling, (Fig. 8.4) *kali* coating (Fig. 8.5) and drying.

Depending upon the number of cuts, there are different types representing pieces of various shapes and sizes (Fig. 8.6). *Api* or *unde* (Fig. 8.6A) is one type which is processed without any cutting. *Batlu* or *ottavettu* (Fig. 8.6B) is cut transversely into two halves. *Choor* (Fig. 8.6C) is produced often by several longitudinal cuttings. There are many sub-groups among *choor* variety like *mukka choor, eda choor, petti choor* etc. in descending order of thickness of the longitudinal pieces. There is yet another variety known as *podi* (Fig. 8.6D) in which the nuts are cut both transversely and longitudinally 3 - 4 times. *Erazels* (Fig. 8.6E) are thin slices which are cut transversely and *chalakudi,* the longitudinal slices.

During the boiling operation involved in *kalipak* processing, usually the same batch of water is used for boiling 3–4 batches of cut arecanuts. The extract so obtained is concentrated to make a thick *kali.* After boiling, the arecanut pieces are given a coating with the *kali.* The *kali* coating can be repeated to get a good glossy appearance.

Fig. 8.2 Dehusking green arecanut for making *kalipak*

Fig. 8.3 Cutting dehusked immature arecanut

Fig. 8.4 Boiling

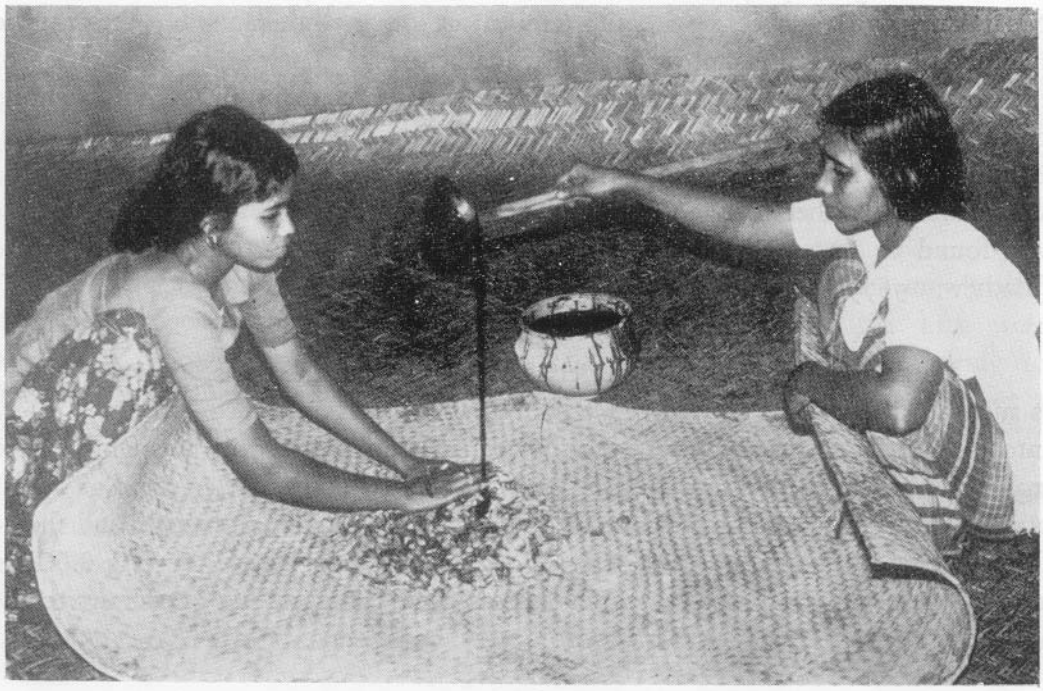


Fig. 8.5 *Kali* coating

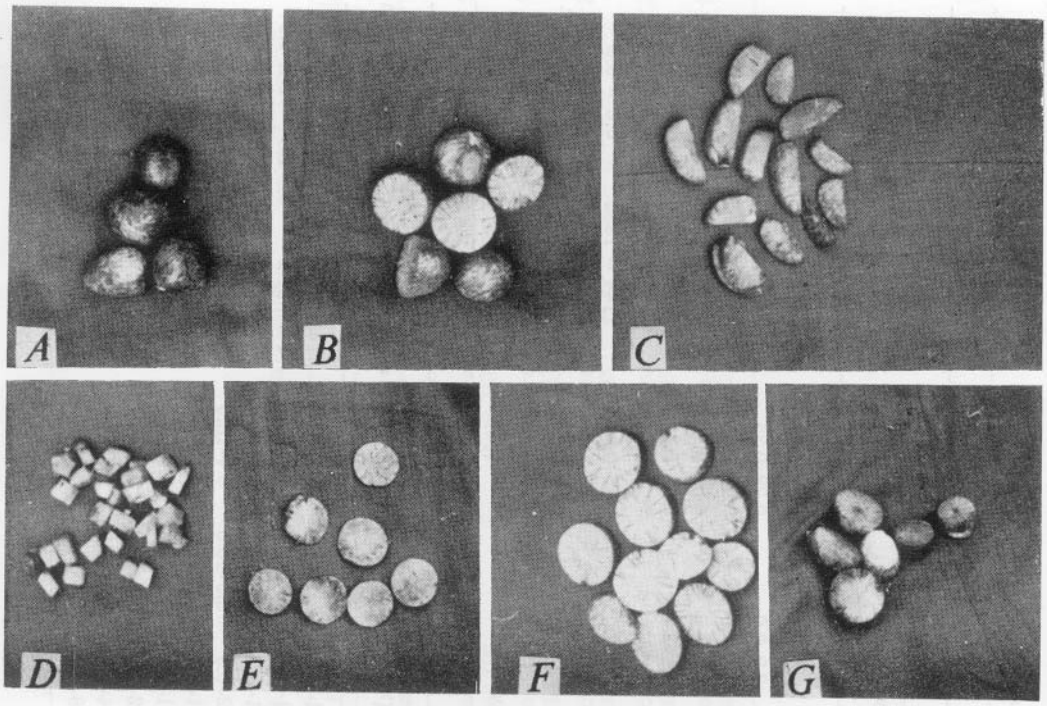
The extracts obtained from processing is concentrated nearly 10-fold by boiling over open fire to produce *kali*. Polyphenols are the major components in it. Fungus growth and thickening of the top layer are the main problems during storage of *kali*. However, when stored in closed containers, the quality remains good.

In interior parts of Karnataka, the boiling and *kali* coating operations are combined into a single operation. For this, the cut nuts are boiled with a thicker extract, which in those parts are known as *chogaru*.

Both sun drying and oven drying are adopted for *kalipak* processing. During monsoon, artificial drying over an open fire is done. Though drying is accelerated, smoky off-flavour is not desirable. A well-dried product with a dark brown colour, glossy appearance, crisp chewing feel, well toned astringency and absence of over-mature nuts, is most welcome and is rated superior.

Sago palm nut is sometimes used as an adulterant in *kalipak*. The cut pieces on *kali* coating are difficult to identify due to similarity in appearance. However, chemical analysis can distinguish between two because the sago palm nuts have higher polysaccharides and fibre contents (Sivasankar, Mathew and Natarajan, 1976). Sweet potato and tapioca are other adulterants; but they can be identified by physical examination. The darkening of *kali* during evaporation of the extracts, is proved to be due to oxidative changes occurring in the polyphenolic constituents, since the extracts boiled with CO_2 do not turn dark (Mathew, 1967). Heating does not increase viscosity, and the increase in viscosity during the *kali* making is therefore entirely due to evaporation. Absorption at 280 mμ was found to increase significantly during the heating after an initial decrease (Mathew, 1967).

There are a few unboiled varieties well known in the trade. *Iylon* (Fig 8.6 F) is such a variety made from green arecanuts in which nuts are cut transversely into 5-6 discs and dried without coating *kali*. The nuts used will be slightly more mature than those used for *kalipak*. *Iylon* is mainly consumed in areas of Tamil Nadu and Andhra Pradesh. Some of the grades in increasing maturity and therefore in decreasing grade are *chittanum, virivu* and *kora*. *Nayampak* (Fig 8.6G) is another variety made from very immature arecanuts after cutting once transversely and drying. *Nuli* is a variety made from very tender nuts.



Figs. 8.6A—G Different types of processed nuts. *A. Unde* or *api; B. Batlu* or *ottavettu; C. Choor; D. Podi; E. Erazel; F. Iylon; G. Nayampak.*

The range of variation in physical and chemical constituents of important processed varieties are given in Tables 8.6 and 8.7 respectively (Sivasankar et al., 1969). Based on these, a possible specification for standards has been indicated (Table 8.8)

3. Scented *supari*

There are many varieties of scented *suparis.* Dried arecanuts are broken into bits, blended with flavour mixture and packed. Formerly the bits were roasted in ghee or oil, but it is almost fully given up nowadays, owing to development of rancidity. The flavouring of *supari* varies with region and is a closely guarded secret.

In South India scented *supari* is made from *kalipak* like *batlu.* Spices and synthetic flavours are added. Instead of raw spices, now a days, essential oils are used for easy blending. Rose essence as well as menthol are very common. Coconut gratings are not added now a days to check microbial growth. These are usually packed in butter paper.

Table 8.6. *Range of variation of physical characteristics of processed arecanuts*

Type/trade names	No. of samples analysed	Range of variation					
		Length		Diameter		Nuts / pieces per kg	Volume per nut/piece in c. c.
		Measurement (in cm)	Standard deviation	Measurement (in cm)	Standard deviation		
Chali	68	0.9–3.3	0.19–0.37	0.8–3.4	0.02–0.38	92 – 840	1.1 –12.0
Parcha	19	1.1–3.0	0.15–0.30	1.3–3.1	0.14–0.31	220 – 522	1.7 – 4.5
Iylon	26	–	–	0.9–3.0	0.09–0.36	800 – 2832	0.4 – 1.3
Api	54	0.6–2.9	0.02–0.30	0.7–3.6	0.03–0.40	158 – 1054	1.1 – 6.5
Batlu	31	–	–	1.0–2.9	0.02–0.27	452 – 1712	0.7 – 2.7
Choor	34	1.0–3.5	0.15–0.40	0.1–2.7	0.03–0.45	912 –16260	0.1 – 1.1
Erazel	9	–	–	–	–	–	–
Chalakudi	3	–	–	1.5–3.0	0.25–0.30	1144 – 1332	0.8 – 0.9
Nuli	5	–	–	–	–	1296 – 3012	0.4 – 0.8

Table 8.7. *Range of variation in chemical constituents* of processed arecanuts*

Types/trade names	No. of samples analysed	Range of variation								
		Moisture (%)	Total water extractives (%)	Polyphenols (%)	Arecoline (%)	Fat (%)	Crude fibre (%)	Total poly-saccharides (%)	Ash (%)	Acid in-soluble ash (%)
Chali	65	5.5–12.2	19.6–39.2	7.3–34.9	0.1–0.7	4.9–24.4	7.1–17.4	14.3–26.3	1.2–2.5	Nil–0.3
Parcha	18	6.2–14.3	23.4–36.4	11.7–25.0	0.1–0.5	12.3–18.1	8.0–14.3	13.0–27.3	1.3–2.1	Nil–0.1
Iylon	25	7.8–10.9	28.7–60.5	19.6–45.9	0.1–0.7	6.8–18.1	5.4–13.3	13.5–28.2	1.4–2.7	Nil–0.2
Api	54	7.4–11.0	23.0–53.3	15.2–41.3	0.2–0.9	5.3–18.5	5.4–18.5	9.2–28.2	1.0–2.5	Nil–0.2
Batlu	31	7.9–13.4	28.3–69.6	22.4–55.2	0.1–0.9	4.3–17.9	3.1–12.3	14.2–27.0	1.5–2.4	Nil–0.1
Choor	33	5.2–11.6	32.4–66.0	24.9–43.7	0.1–0.9	5.9–17.8	5.1–15.2	11.1–28.1	1.2–3.3	Nil–0.5
Erazel	9	7.7–11.6	29.6–57.4	16.9–38.0	0.2–0.8	5.5–12.3	5.9– 8.7	13.1–26.6	1.5–5.0	Nil–1.2
Chalakudi	3	9.2–10.2	49.8–57.0	32.0–39.3	0.4–0.9	7.1–10.5	5.3–14.9	22.1–26.9	2.3–3.6	Nil–0.1
Nuli	6	9.2–10.6	53.0–72.4	39.0–47.9	0.6–0.9	3.7–13.8	3.8– 6.0	16.4–22.7	2.1–3.2	Nil–0.2

* All values except moisture are on dry basis

Table 8.8. *Specification of significant chemical constituents for the major types of processed arecanuts*

Types/ trade names	Moisture (%)				Total water extractives (%)				Polyphenols (%)				Crude fibre (%)				Ash (%)				Acid insoluble ash (%)			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Chali and parcha	8.7	1.5	17.0		25.7	3.3	12.9	Not less than 19%	16.1	4.7	29.4	Not less than 10%	10.7	2.2	20.8	Not more than 18%	1.6	0.2	14.0	–	0.01	0.04	314.3	–
Iylon	9.6	0.8	8.6		42.2	10.8	25.6	Not less than 27%	32.9	4.0	12.1	Not less than 19%	8.2	1.6	19.8	Not more than 14%	2.2	0.7	30.7		0.14	0.57	379.3	
Api	9.2	0.8	9.3		32.9	7.7	23.4	Not less than 23%	23.7	5.6	23.8	Not less than 15%	8.3	2.9	35.1	Not more than 15%	1.8	0.3	17.7		0.02	0.07	226.7	
Batlu	9.6	1.4	14.4		46.3	9.9	21.5	Not less than 28%	34.3	7.5	22.0	Not less than 22%	7.3	1.9	26.7	Not more than 13%	2.1	0.3	15.4		0.01	0.03	215.4	
Choor	9.4	1.1	11.8		45.3	8.4	18.6	Not less than 32%	31.8	4.4	13.7	Not less than 24%	8.2	2.1	25.8	Not more than 13%	2.3	0.6	25.0		0.06	0.13	200.0	

Not more than 11% (Moisture 4)

Not more than 3% (Ash 4)

Not more than 0.2% (Acid insoluble ash 4)

1 = Mean; 2 = Standard deviation; 3 = Coefficient of variation; 4 = Specification.

Scented *suparis* popular in north and central India are of two types: the one made from *chali* and the other from *kalipak*. The former is more popular. At times, saccharin is used for sweetening. Additives like colour and flavour are added. Plastic strips are used for convenient packing. Tin and aluminium pouches are used for bulk packing of scented *supari*.

There are well known 'flavour houses' which can readily supply the desired flavouring essence to producers of scented *supari*. This is a great boon to entrepreneurs in the selection of flavour blend. The essence can be easily mixed with *supari* to give a homogenous product.

The *kalipaks* and scented *suparis* are used mainly as a masticatory, whereas *chali* and ripe arecanuts which leave a large fibrous residue in the mouth are used along with betel leaf and slaked lime. Ready made combination of these are known as *beeda* and often flavoured with spices like cloves, coconut gratings and sugar crystals. In North India, the *paan-beedas* contain *katha*, the extract of *Acacia catechu* also. About 75 per cent of the marketed produce is consumed after processing, either as *kalipak* or *chali*.

III. Taste characteristics

Astringency is the characteristic taste of arecanuts. Polyphenols which are present abundantly in it are responsible for this. Astringency is felt as a contracting and drying sensation or puckeriness felt all over the mouth. Elaborate studies on astringency of areca polyphenols have been carried out by Mathew (1967). The polyphenols after fractionation into catechin, leucocyanidin (monomer) rich in oligomeric proanthocyanidin and polymeric fraction have been subjected to sensory evalution (Table. 8.9). The monomeric fractions elicit the characteristic choking and drying effect. The oligomeric and polymeric fractions delay effect in sensing astringency. The astringent characteristics in arecanut decreases with maturity.

The chief requirement for this sensation appears to be a fairly high molecular weight and a large number of phenolic groups rather than any specific skeleton. The mechanism by which astringency is felt, is also subject to many speculations. One hypothesis pictures cross-linking between the active centres of polyphenols with the mucoproteins in the mouth. The threshold of astringency of areca polyphenols has been found to be 0.025% level in the tongue (Mathew, 1967).

Table 8.9. *Organoleptic qualities of areca polyphenolic fractions**

	Catechin (monomer)	Leucocyanidin (monomer)	Oligomeric fraction	Polymeric fraction
Astringency (score)	Intense (10)	Intense (10)	Good (8)	Fairly good (7)
Colour	Reddish	Yellowish	Yellowish	Yellowish
Odour	Earthy	–	–	–

* As 0.5% solutions

IV. Colour development on chewing

The chewing of arecanut with betel leaf and slaked lime is very popular in India and neighbouring countries. In addition to the stimulation and pleasant taste, chewing results in bright red colour of the mouth. Mathew (1971) reported that catechin turns brilliant red immediately after addition of alkali (pH 10) which gradually turns reddish brown on standing for more than two hours. Similarly, the leucoanthocyanidins, which become dark red initially, turn dull brown in about two hours and pale brown on keeping over-night. The polymeric proanthocyanidins, which contain mostly leucocyanidin units also behave similarly. The colour change of all the compounds at pH 8 is basically similar though rate of change is different. The pH of normal chew is also found to be in the same range of 8–9. Under the mild alkaline condition of the chew, the o-quinones formed will be dark red in colour. These, on standing for more than 2–3 hours polymerise to give complex secondary products of dull red colour. The secondary oxidation products in the residues of previous chews, impart a dull red colour to the mouth of the chewer.

It is concluded that the red colour formed during chewing is due to o-quinone formation from water soluble polyphenols, notably leucocyanidins, under the alkaline pH and subsequent secondary reactions. Betel leaf has no contribution to the formation of red colour. However, it contributes to the freshness of flavour due to the phenolic essential oil present in it.

V. Quality aspects of processed arecanut

The quality aspects of processed arecanut are extremely important. However, systematic studies are rather limited. Descriptions of market types of processed arecanut have been compiled by Shamanna (1951). A more systematic evaluation based on physical, visual and organoleptic factors has been attempted by Dhanaraj et al., (1970).

The quality factors for dry ripe arecanuts have been identified (Dhanaraj et al., 1970). The preference for a particular size differs with region. Thus in Bombay market, big size is most preferred whereas in Nagpur, Jamnagar and Allahabad small size is in good demand. However, in all markets, uniformity of size appears to fetch a premium price. The colour of nuts also matters. Nuts having light brown skin colour and a clear core with a smooth cut surface revealing white polysaccharide portions interspersed with well defined brown veins, are considered superior. Greying and yellowing are indications of poor quality. The presence of dried tender nuts with a darker colour is also a defect. The nuts should be devoid of husk and other extraneous matter. When there is perceptible surface cracking of nuts, the quality of the product is considered to be inferior because this indicates improper drying and presence of immature nuts. However, a few markets in Calcutta and Cuttack accept these, to be sold after breaking into pieces. The signs of cracking found in the interior white core of the nut are indicative of proper drying and are always accepted. The traders, also look for good cutting feel and smoothness of nuts. Fungus and insect infestation are highly undesirable. During auctioning of the nuts, the taste characteristics are not judged, usually. However, nuts with mild astringency and sweetness are believed to be more desirable. In the case of market samples of *chali* and *parcha,* it has been generally observed that size variations and poor skin colour are very common. However, the cracks and splits are less frequent. Tender dried and fungus infested nuts are not uncommon and price deductions for these defects is rather high.

In the case of *kalipak* each variety has a particular size and shape decided by the type of cutting (Dhanaraj et al., 1970). *Kalipaks* made in coastal regions are found to have thick *kali* coating and dark, glossy appearance, while in interior parts like Mysore, a thin coating of *kali* is usually done. Dullness, discolouration and patches are all defects in *kalipak* variety. *Iylon* has a light colour, being an unboiled variety. The inside structure of cut pieces gives an idea about the maturity of the nuts used for. Matured nuts will be fibrous whereas tender ones and over dried samples are brittle. The maturity factor is very important in the trade. Bacterial spoilage and infestation are considered a serious defect. *Kalipaks* are rated good if they are crisp to bite whereas the *iylons* can be slightly fibrous to chew. Absence of rancidity and smoky off-flavour is always looked for. A quality *kalipak* is expected to have more astringency than a *chali* product. The *kalipak* should provide a mild and pleasant feeling of slight intoxication and characteristic taste and very mild after-sweetness. Excessive astringency and off-taste are defects.

In *iylon* and *api* samples, surface characteristics are the deciding factors. Tenderness of the nuts as judged by the outside appearance is an important quality. In *choor* and *batlu* samples, uniformity of nuts, size variations, surface characteristics are given only moderate importance and do not alter the price much. The cutting feel is taken as a measure of the moisture content but on close examination, it is revealed that this is not true because quality is decided by nature of drying rather than merely the final moisture content. The overall texture of the nut and its chewing feel depend on maturity. It is generally observed that traders attach less importance to astringent characteristics of the nuts. They judge the product mostly by visual examination. Absence of rancidity, smokiness and microbial spoilage are always checked for. The price evaluation based on the quality assessment of the various products holds good in most cases. However, deviation from the expected price based on quality evaluation with the market price takes place when there is time lag between evaluation and actual marketing of the samples assessed during which time deterioration of quality may take place. The selling price depends upon the demand and supply as well as fluctuations in cost of living.

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9

PHARMACOLOGICAL PROPERTIES

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Arecanut has long enjoyed a reputation in India and China as an anthelmintic in man and particularly in veterinary practice. The fresh nut has intoxicating properties and produces giddiness. The ripe nut is astringent and is now used only in the veterinary practice as a vermifuge. Pharmacological work carried out on arecanut for the last few decades is summarised in this chapter.

Vagbhata's (4th century A.D.) reference to arecanut is probably the earliest reference in any text. He describes its use in the treatment of leucoderma, leprosy, cough, fits, worms, anaemia and obesity. Arecanut is recommended as a purgative, and in an ointment for the treatment of nasal ulcers along with other ingredients. Bhavamisra (13th century) recommended the use of arecanut for its appetizing and stimulating properties.

I. Constituents of arecanut

Out of the five alkaloids present in arecanut, arecoline is the main and physiologically most active alkaloid present to the extent of 0.07–0.1 per cent. The structure of arecoline has been ascertained by synthesis as well as its relation to other alkaloids of this group. Trier (1913), Freudenberg (1918) and Emde (1915) have elucidated the structures of other alkaloids present in arecanut in trace amounts. Figure 9.1 shows the structure of arecanut alkaloids.

Watt (1889) mentions that arecanut powder is used as an anthelmintic for dogs to expel tapeworms and threadworms. Nadkarni (1908) mentions that arecoline which is isolated from arecanut, resembles muscarine and produces a fall in blood pressure. One per cent solution of the alkaloid constricts the pupil like physostigmine. The tincture of nut is used for bleeding gums after diluting with water. The juice of tender leaves mixed with oil is applied in cases of lumbago

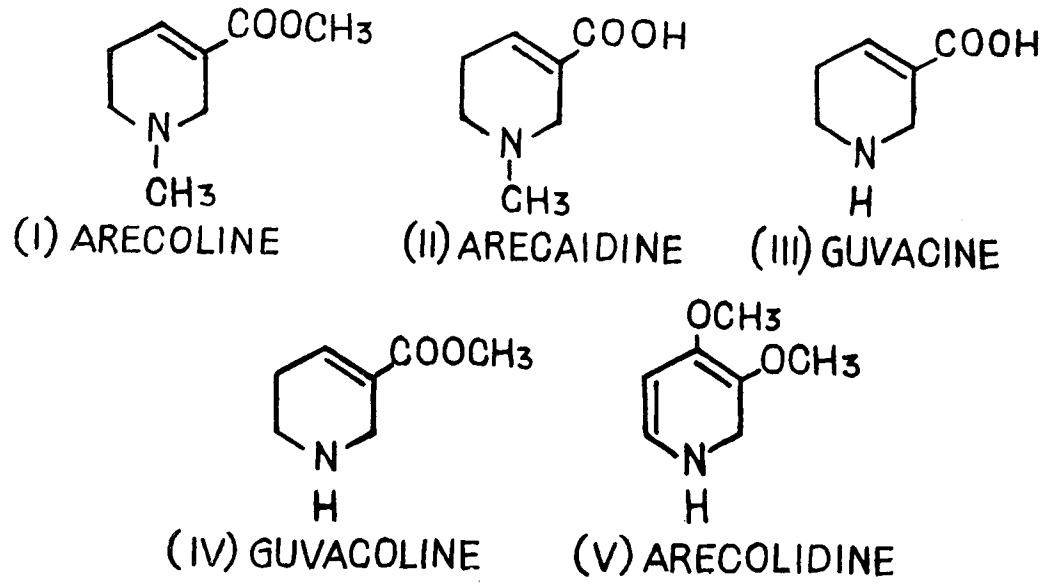

Fig. 9.1 Arecanut alkaloids

and decoction of the root, cures sore lips. Desai (1927) reported that roasted arecanut is useful in dysentry. Chopra (1933) mentioned that the nut is useful in hookworm infection. It is evident that arecanut has long been in use as medicine in India along with other parts of the palm.

II. Anthelmintic activity

Arecanut alkaloids, particularly arecoline is known to be effective on various helminths since long. As early as in the sixth century, Chinese used betel nut as vermifuge (Goodman and Gilman, 1975). Many workers in the past had claimed the use of arecanut in the treatment of helminthic infections in human beings as well as animals in combination with other drugs (Finger, 1944; Hoffman and Held, 1953; Galvin, 1957; Stoican et al., 1962; Hermoso and Monteoliva, 1970).

The arecanut decoction as well as arecoline and its salts have been found to be effective in taenia infections. Feng et al., (1949) observed that paralysis of the worm was due to the action on nerves. Feng (1949) supported this observation by giving decoction, crude extracts and bismuth iodide salt of arecoline in clinical trials. Sia (1959) recommended arecanut decoction and magnesium sulphate as a purgative, after a prior treatment with pumpkin seed powder. Arecoline hydrobromide, 4mg per kg (oral or subcutaneous) dose was effective

against taenia, while its efficacy was doubtful in ascariasis and anclostoma infections (Cacho-lopex, Miller and Mc Gregor, 1963). In multiple infections in dogs, single dose of arecoline hydrobromide removed all multiceps and most of the taenia, while multiple doses for seven days removed the common infection of *Echinococcus* also (Forbes, 1964).

Various authors have reported the efficacy of arecoline salt against *Echinococcus granulosus* infection, which is common in canine animals (Gelormini, 1941; Patune, 1958; Gomez, 1969). Sims and Sanchez (1979) have successfully treated 4966 cases of *Echinococcus* infection in dogs with arecoline hydrobromide. Other animals like mice, ducks and geese have also been effectively treated with arecoline against *Hymenolepis* infection (Inagaki and Hisada, 1956; Cavier, 1956; Vasiler, 1957).

Barker (1966) suggested that the elimination of *Schistosoma mansoni* worms was due to blockade of cholinergic system. Arecoline is reported to be useful in infections like fasciolopsiani cestode, ascariasis, heterales and *Rallietina* sp. (Gaibov, 1959; Duguid and Heathcote, 1950; Nikitin, Yakovlev and Kochetov, 1963), while it is ineffective in spirurides and hookworm infections (Ehler, 1931).

III. Parasympathetic action

Pilocarpine, muscarine and arecoline are important natural alkaloids which stimulate autonomic effector cells as those acted upon by cholinergic post-ganglionic nerve impulses. These compounds show the central stimulant action. As a result, bradycardia, hypotension, increase in intestinal tone, salivation and sweating are produced. These actions are antagonised by atropine (Leslie, 1965). Muscarine acts almost exclusively at muscarinic receptor sites, while arecoline acts in addition, at nicotinic receptors (Von Euler and Domeij, 1945). The ganglionic stimulant action of arecoline is due to activation of nicotinic receptors, in that it is blocked by nicotine and relatively resistant to atropine. The arecoline is as potent as acetyl choline and stronger than pilocarpine, eserine and muscarine on the intestine (Kegr, 1933; Henderson and Roepke, 1937). Arecoline increases the tone and rhythm of the smooth muscles of alimentary canal, while atropine antagonizes this effect and ephedrine is inactive (Breslan, 1911; Epstein, 1931; 1932). Kuchler (1933) showed that these effects were due to local diffusion of drug from the intestinal lumen. Others have suggested that the effect was also due to acceleration of liberation of acetyl choline at that site (Takagi, Takayanagi and Swin, 1967). The muscarinic effect was found to be

independent of pH (Hannin, Donald and Cho, 1966). The subcutaneous injection of arecoline salt causes salivation (Sharma, 1936; Awe, 1967; Hassko and Gurgen, 1939). The arecoline iodomethylate is less potent than arecoline hydrobromide (Kadonaga, 1938). At presynaptic sites arecoline appears to be useful for liberation and maintenance of neurotransmitter (Semenov and Krylov, 1979).

IV. Cardio–vascular activity

Cardio–vascular effects of arecoline are mediated through the cholinergic system, as these effects are blocked by atropine. It is effective by both subcutaneous and intravenous routes. The cardiac depression is brought about through vagal stimulation (Heymans, 1922). Von Saalfeld (1931) found that arecoline constricted the coronary artery of a reptile. It diminished the amplitude of contraction of the ventricle, when A–V bundle was kept intact on isolated rabbit's heart. This was dependent on S–A nodal rhythm. The idioventricular rhythm, which is obtained after section of A–V bundle, is not affected (Dale, 1930). Schewarte and Dukes (1931) and Braude (1937) showed that cardiac standstill brought about by arecoline was reversed by UV radiation, while IR radiation accelerated the action. Trusserich (1935) found that the susceptibility of isolated cat's heart to extra systole caused by aconite was potentiated by arecoline. An aqueous extract of arecanut with adrenaline hydrochloride showed both direct vaso–constriction and adrenaline potentiation after hind limb perfusion in rats (Sirsi, Dorle and Govindarajan, 1963).

Kadonaga (1940) reported that arecaidine hydrochloride had no effect on isolated heart of frog, while arecaidine methyl iodide caused depression. This action was not influenced by atropine. According to Reis (1967), the arecaidine, like acetyl choline, causes contraction of rat diaphragm. The quaternisation of arecaidine ester shows higher affinity and intrinsic activity than tertiary compounds. The double bond in the ring reduced the action. The possible mechanism of action is through depolarization of denervated muscle.

V. Urine and electrolyte excretion

Williams and Carter (1965) showed that arecoline hydrochloride (1.25 – 3.0 mg/kg subcutaneously) produced marked natriuresis and chlorouresis in hydrated rats. This action is purely muscarinic since, it is blocked by atropine. Williams and Carter (1965) found the same effect after unilateral renal arterial infusion of arecoline hydrobromide in 1–10 μg per kg dose. It has some direct

effect on renal haemodynamics, as it affected the effective renal plasma flow. Arecoline increased Na, K and osmolity of urine without urine volume (Avrunin and Carter, 1967).

The diuretic action of the drug is postulated to be due to overwhelming pumping mechanism responsible for removal of sodium ions from the cells caused by an increase in the permeability of the peritubular membrane to sodium. Net results of these two mechanisms were the decreased ingredient for sodium movement from tubular lumen into tubular cells which would result in increased sodium and water excretion (May and Carter, 1967). They further noticed that the above effect was independent of vasodilation and was due to direct inhibition of proximal renal absorption of sodium (May and Carter, 1970).

VI. Ocular effects

Miotic effect of arecoline has been known since a long time (Fracassi, 1921). Similar action was noted *in vitro* by Young (1933), on excised sphincter muscle of iris. This effect is muscarinic in nature. Kmilov (1936) showed that, potassium salts have synergistic action on miosis caused by arecoline, eserine and pilocarpine. This could be due to increased cell permeability produced by these salts.

Tsukamoto and Kumori (1955) and Lee (1957) have observed that areca alkaloids accelerate the regeneration of visual purple. Arecaidine hydrobromide suppresses rhodopsin regeneration, while arecaidine hydrochloride promotes the same (Toida, Kuriyama and Kumori, 1957). The alkaloids are supposed to promote the regeneration of rhodopsin *in vivo* but not *in vitro*. This action is probably due to acceleration of rhodopsin regeneration by activation of the functional components other than, the outer segments of the rod (Kumori, 1961). Arecoline and non-arecoline showed miotic activity. Non-arecoline fraction is more potent than arecoline as shown in Table 9.1. The non-arecoline (yield 0.87–1.6% of arecanut), was further fractionated to yield two fractions. The major fraction was inactive, while minor fraction was active. On further fractionation, crude minor compound was separated showing miotic activity (yield approximately calculated as 0.001%). The chemical characteristic of this compound was not possible to determine due to low yield and instability of the compound. Since yield of the active compound is very meagre, there is least possibility of getting any commercially useful product. However, if the nature of the compound is known, it may be a new addition to the biologically active compounds which may be synthetized.

Table 9.1. *Miotic activity of arecoline and non-arecoline fraction on rabbit eye*

Effect at	Pupillary diameter in mm		
	Control	1% arecoline	1% non-arecoline
Initial	8	8	8
Onset	8	7 (5 min.)	6 (5 min.)
Peak	8	5 (25 to 35 min.)	3 (20 to 45 min.)
Recovery	8	8 (60 min.)	8 (75 min.)

VII. Central nervous system

The CNS actions of arecoline are muscarinic in nature. The actions of arecoline are biphasic, as they increase and decrease spontaneous motor activity, water and food consumption, as well as food reinforcement, at low and high doses, respectively. The depressant action of arecoline is antagonised by scopolamine, but not by methyl scopolamine and mecamylamine (Pradhan and Dutta, 1970). The depressant action of arecoline is of parasympathetic type. The arecoline gets converted into arecaidine in liver, which is devoid of parasympathetic action. Arecaidine has sedative property only in higher doses (Neischulz and Schmersahl, 1968).

Herz and Yocoud (1964) showed that, arecoline inhibits conditioned avoidance responses (CAR). This action is blocked by atropine and atropine methyl nitrate, suggesting cholinergic mechanism (Nikiforov, Gorodnik and Lesnoi, 1968; Stern, 1968). Schweitzer and Wright (1937) showed that pilocarpine and arecoline are purely convulsant drugs. The convulsions produced by arecoline are cholinergic (Peciffer and Jenney, 1957). The arecoline induced tremors and inhibition of CAR are reversed by methyl atropine nitrate (Stern, 1968). The $CuCl_2$, chlorpromazine, and histidine potentiate the static tremors caused by arecoline and oxotremorine (Herz, 1962).

The cholinergic drugs causing cataleptic state and hypothermia in mice, are antagonized by anticholinergic and antidepressant drugs, respectively (Zetler, 1968). The choline ester and peripheral muscarinic drugs like arecoline, administered by intracerebro ventricle route, in unanaesthetized cat, evoked emotional, behavioral and autonomic changes as well as motor phenomena with convulsions suggesting central muscarinic cholinoceptive site of action (Belesin,

Leposava and Radmanovic, 1974). Arecoline was shown to induce aggressive behaviour in unanaesthetized cats (Belesin and Samardzic, 1979). The cataleptogenic potency of various drugs like morphine, haloperidol and arecoline is enhanced by exerting pressure upto 1000 mm of Hg on mouse tail (Ariyanagarm and Handley, 1975).

The antinociceptive action of arecoline was reported by Herz (1962). This action was blocked by atropine, but not by methyl atropine. The analgesic action and the condition avoidance response, were observed at similar dose levels. The mechanism of action of arecoline is different from that of morphine, since it is not modified by scopolamine. Secondly, analgesic response of arecoline is associated with decrease in motor activity, as opposed to other analgesic drugs, like morphine which stimulates motor activity (Mattil, Ahte and Saarnivaara, 1968). The analgesic response of arecoline is reduced by histidine and $CuCl_2$ (Stern, 1968). Nehring, Schermber and Andreas (1975) studied effect of noradrenaline and serotonin on arecoline analgesia. The noradrenaline and serotonin on administered by intracerebral route in mice reduced and strengthened respectively the nociceptive reaction. The antagonistic action to arecoline is shown by p-chlorophenylalanine and reserpine. In unanaesthetized rat, prostaglandin E_2 induced hyperthermia is prevented by icv. arecoline, where aspirin was ineffective (Gurin, Traryule and Tretyakovich, 1979).

Arecoline penetrates the blood brain barrier like other muscarinic drugs (Olds and Domino, 1969). The mechanism of action of arecoline is different from that of other muscarinic drugs, thus, arecoline seems to produce effects by central nervous system action alone (Tsujimoto et al., 1975).

Arecoline is known to prevent halothane induced shivering and delay the return of normothermia. This effect is antagonised by atropine, but not by methyl atropine (Nikki, 1968). It was also observed that the arecoline prevented shivering both in euthroid and hyperthroid mice, while the return of normothermia was rapid in hyperthroid mice it was delayed in euthroid mice. (Nikki, 1969) In conscious mice, arecoline caused hyperthermia in euthroid animals. But, tremors were observed in both groups. The prevention of halothane shivering by thyroid treatment is a result of increased calorogenic effect.

Arecoline evokes muscarine like activating response on the electroencephalogram (EEG) of enecephaleisole preparation of the cat. From dose response curve, the threshold dose was found to be 1 μg per kg intravenous, which also evo-

ked peripheral parasympathetic effects. Atropine methyl nitrate elevated only moderately the threshold for arecoline-induced activation response. The activation response of arecoline was unaltered by atropine or atropine methyl nitrate-pretreated animals (Reiehl, Paul-David and Unna, 1962).

VIII. Miscellaneous activities

1. Antimicrobial activity

The aqueous extract of arecanut inhibited the growth of *Staphylococcus aureus* and *Trichophyton rubeum.* The alcoholic extract showed wider spectrum of activity, inhibiting the growth of *Escherichia coli, Candida* and other species of *Trichophyton,* and *Staphylococcus aureus.* The antimicrobial activity was not associated with alkaloidal fraction. The aqueous and ethyl acetate fractions were inhibitory in 100 ppm dilution. The compounds like polyphenols present in the ethyl acetate and water extracts were possibly antimicrobial and antifungal agents in the nut (Lalithakumari, Sirsi and Govindarajan, 1975). The arecoline was effective at 200 r per ml against *Mycobacterium tuberculosis* (Fitzpatrick, 1954).

2. Antifertility activity

The various extracts of arecanut, in petroleum ether, alcohol and water showed antifertility effect (Garg and Garg, 1971), Rafaelskaya (1980) showed that in male white rat arecoline causes morphofunctional changes such as stimulation of hormogenesis and disrupt spermatogenesis.

3. Carcinogenic activity

Balendra (1949) showed that buccal carcinoma was not directly caused by betel chewing, but possibly, due to continued irritation. In hamster, DMSO extract of arecanut on topical application, resulted in leucoplenia (90%) and tumor (38%). Boyland (1968) reviewed the carcinogenic effect of alkaloids of tobacco and arecanut. Syed, Rao and Mustafa (1980) noted the inhibition of humoral and cell mediated immune response in mice after arecoline treatment. This immunosuppressive effect may facilitate betel quid induced oral and oesopharyngeal carcinoma. The aflatoxins B and G, which are known carcinogens have been isolated from spoiled arecanut (Thuan and Amarasingham, 1978).

Arecoline (24 mg/kg/day) injected subcutaneously in rats for 45 days, caused cytoplasmic vacuolization, pycnosis and beta cells karyolysis in the pancreas. In *in vitro* conditions, arecoline in weak concentration increased and in higher concentrations, decreased the growth of fibroblast. Higher doses produce rapid

degeneration (Kawashima, 1932). The arecanut powder defatted by petroleum ether extraction used in chewing by volunteers, who usually got mucus membrane irritation of oral cavity leading to ulcers, did not show such effect after defatting. It is likely that along with fat, some irritant compound might be extracted.

4. Hypoglycemic activity

Lang and Rigo (1928) studied the effect of various parasympathetic drugs on blood sugar level of guinea pig. Arecoline at 0.05–0.25 mg per kg dose caused hypoglycemia (27–42 per cent) and at 0.5–1.0 mg per kg dose produced hyperglycemia (23–29 per cent). Arecoline is known to cause hyperglycemia in normal rats and hypoglycemia in adrenalectomized rats (Gurin and Bagritsevich, 1972). The ergotamine is supposed to produce hypoglycemia, hence pretreatment with ergotamine prevents the hyperglycemia caused by arecoline. If ergotamine is given simultaneously, it has no effect, and if given half an hour later, it hastens the return of blood sugar to a normal level (Carbonard, 1931). Arecoline hydrochloride at 0.5 mg dose decreased blood sugar level (Nakayasu, 1935).

Hypoglycemic and hyperglycemic effect of arecoline at low and higher doses respectively have been confirmed by the recent work at the Indian Drugs Research Laboratory, Pune. However, arecoline has no significant effect on alloxan induced diabetes eventhough, it reduces the blood sugar level.

5. Other metabolic effects

Kiyohara (1931) observed that arecoline at lower doses depresses glycogen mobilisation in toad liver. This action is reversed at higher doses. Arecoline also decreases lipase contents of arterial blood, with retention of lipase in the kidney (Sharikova and Rapoport, 1939). Like pilocarpine, it causes a prolonged decrease in createnine content in the pigeon muscle. Gurin (1971) studied the influence of arecoline-like drugs on consumption of free fatty acid and activity state of pituitary adrenocortical system. Arecoline did not affect either the Na^+ K^+–ATPase nor the Mg^{2+}–ATPase activity, while glutathione, significantly inhibited steriatal Na^+K^+–ATPase without affecting Mg^{2+}–ATPase. This effect was partially reversed with arecoline. Thus arecoline may activate the pentose-shunt mechanism like acetyl choline (Von Schwarzenfeld, Fischer and Delszner, 1974).

Arecaidine exerts a vasomotor and secretory influence upon adrenals through the parasympathetic system (Romm and Serduk, 1927). Direct injection of arecoline into the adrenal gland resulted in increased secretion of adrenaline (Houssay and Molineli, 1926). Gurin and Loginov, (1969) observed that

arecoline appreciably lowered the concentration of ascorbic acid in adrenals of rats receiving reserpine. The action could be explained as the excitation of central m-cholino-reactive structure which activates the hypophysio-adrenocortical system.

Arecoline increases excretion of carbon dioxide and water and absorption of oxygen in rabbits (Preobrazhenskii, 1929). It diminishes the rate and amplitude of phrenic nerve action potential. Its application to fourth ventricle fails to provoke inspiratory aponea like other cholinergic drugs. Application to medulla oblongata, through vertebral artery results into expiratory aponea. Exact mechanism of these effects is not known (Ger, 1967). Arecoline hydrobromide is used in an antisnoring composition, which was formulated into gargles and tablets (Khoe, 1975). Basu, Basak and De (1942) have reported that lime with betel nut chewing meets the calcium deficiency of Indian diet.

IX. Metabolism

Arecolin given by mouth acts locally on the gut to produce the therapeutic effect of purging and side effects like vomiting. This is probably due to its absorption through mouth, pharynx and lungs (Forbes, 1964).

Robinson (1927) studied the absorption of arecoline by vagina which was indicated by its effect on blood pressure and respiration.

Excretion of arecoline was studied by Huber (1922). He detected arecoline in saliva but not in stomach indicating excretion through saliva.

The activity of arecoline remained unchanged, when incubated with brain homogenate, while it was reduced with liver homogenate. This may be due to conversion into arecaidine in liver. The toxic effects of arecoline are not associated with arecaidine (Nieschulz and Schmersahl, 1968).

Arecoline is converted into arecaidine in rat, and both get converted into N-acetyl-S-C3-Carboxyl-L-methylpiperid-r-yl-L cystin and an unidentified metabolite (Boyland and Nery, 1969).

X. Structure-activity relationship

Arecoline bears a certain structural resemblance to nicotine, as pilocarpine resembles histamine. Arecoline and pilocarpine are tertiary amines. But, the

former has been shown to be pharmacologically active in protonated form (Vanrossum, 1962). Most of the muscarinic compounds are quaternary ammonia derivatives except arecoline and pilocarpine. When they are converted into tertiary forms, the activity is lost or reduced. Yamashita (1958) studied the effect of various salts of areca alkaloids. Out of several salts, only arecoline hydrobromide, arecoline methyl iodide, arecoline hydrochloride and arecaidine hydrochloride were parasympathetic in nature. Thus, —$COOCH_3$ group at C–3 position in pyridine ring is responsible for the parasympathetic action. Further, Tsarev (1952) observed that arecoline hydrochloride was stronger parasympathetic agent than arecoline methyl iodide. Both synthetic as well as natural arecoline hydrobromide were equipotent for anthelmintic activity (Tsare, 1952; 1953; 1956; 1957; Fecoktistov, 1953). Out of other derivatives of arecoline and propyl arecoline, only propyl arecoline was pharmacologically inactive (Tsarev, 1955).

Alkaloids of arecanut with the quaternary ammonium base stimulate vagal activity. Compounds with tertiary nitrogen base and zwitterions are inactive as a class.

The comparison of the effects of tertiary and quaternary arecaidine esters and dihydro-compounds on isolated ileum were investigated by Rudenko and Zakharova (1965). The ethyl and methyl esters were active, while ester with longer side-chains were less active. The intrinsic activity of ethyl ester of arecaidine was higher than that of acetyl choline. The hydrogenation of double bond in ring reduced the intrinsic activity of the tertiary arecaidine esters. The quaternisation by iodomethyl-ethylation of arecaidine esters reduced intrinsic activity, while ethyl ester became partial antagonist. Similar transformation of ester of long chain leads to the complete loss of intrinsic activity. The hydrogenation of double bond in the ring of quaternary compound diminished the activity. The aliphatic nitrogen quaternisation is essential for muscarinic action. In arecaidine, ester quaternisation of ring nitrogen atom reduces or even destroys intrinsic activity in proportion to the length of the ester side chain.

The amplitude of electrically stimulated contractions of guinea pig atria is reduced by all tertiary arecaidine esters, while quaternary are ineffective. Arecaidine ethyl ester has the highest affinity for acetyl choline, while the corresponding isopropyl ester is least active in this series (Konig, Lullaman and Mutschler, 1967).

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10

ALTERNATIVE USES OF ARECANUT

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Arecanut has been widely used since long throughout south and south-east Asia and the Pacific Ocean Islands. While its primary use has been as a masticatory, it was also finding use among the local populations in native systems of human and veterinary medicine, in certain religious and social functions and in farms and households (packaging, construction), etc. With the development of modern systems of medicine, the use of arecanut fruit, leaves, stems and roots for medicinal purposes steadily began to wane.

The use of arecanut as a masticatory has been declining since the last 2-3 decades with the incursion of modern ways of living into the lives of the rural people, particularly in south-east Asia. It has been in this context that studies on developing alternate and better uses for arecanut were taken up by the erstwhile Indian Central Arecanut Committee in the fifties and since the early seventies by the Indian Council of Agricultural Research under the auspices of the CPCRI Regional Station, Vittal.

In this chapter a brief review of the varied uses for which betel nut has been put to in south and south-east Asia has been given along with summaries of the work carried out on alternative uses of arecanut under the various schemes.

I. Uses of various constituents of nuts

The quest for developing alternate uses for arecanut has been based on finding best uses for the various constituents of the nut. Studies carried out on the utilization of constituents of arecanut like tannins and fats are given below.

1. Tannins

Long before the nature and properties of tannins were determined, the tannins in arecanut were being made use of, for dyeing clothes, rope etc. and for tanning leather for home use in south-east Asian and Pacific Ocean countries. (Watt, 1889; Burkill, 1935; Baens, 1941; Brown, 1952).

Tannins are obtained as a by-product from the process of preparing immature betel nuts for masticatory purposes. In this, the immature nuts are husked, and boiled in water or a mother liquor left over from the earlier boiling, either as whole or after cutting them into two or more pieces. This liquor containing considerable quantities of tannins is known as *chogaru* or *kali*. The sediments found in the liquor when dried is called arecanut dust. The dust and *chogaru* are traditionally used as a masticatory or for tanning leather.

Raghavan (1957) found that tannic acid or gallic acid from the nut, when mixed, with ferrous sulphate in warm distilled water gave black writing ink of acceptable quality. He used immature fallen nuts for this purpose.

Banerjee and coworkers (Banerjee, Ghani and Nayudamma, 1963) have studied the physico-chemical characteristics of areca tannins as compared to wattle tannins. They compared the water extractives of tender arecanut with concentrated *chogaru* liquor, arecanut dust available as by-products of arecanut processing and commercial *Mimosa* extract, for non-tan (salt) ratio, gelatine number, rate of diffusion etc. The results are given in Tables 10.1 and 10.2.

Table 10.1. *Analytical data of different tanning materials*

Analytical data	Tanning materials				
	Tender arecanut (air dried)	Arecanut dust	*Chogaru* liquor	*Mimosa* extract	Aqueous extract of arecanut
Moisture (%)	15.2	13.47	48.28	10.35	11.71
Total solubles (%)	16.49	23.77	27.22	87.25	81.38
Tannin (%)	9.86	13.94	15.55	66.73	43.16
Non-tannin (%)	6.64	9.83	11.67	20.52	38.22
Tannin/non-tannin ratio	1.48	1.42	1.34	3.25	1.13
Insolubles (%)	68.31	62.76	24.50	2.40	6.90

Table 10.2. *Acid and salt constituents of different tanning materials*

Tanning material	pH of the liquor of 20° Bk strength	Weak acids mg. eq/litre of 100° Bk	Salts of weak acids mg. eq/ litre of 100° Bk	Ratio of weak acids to their salts	Buffer index
Arecanut	4.6	55.0	285.0	0.19	2.22
Chogaru liquor	5.0	50.0	300.0	0.17	2.33
Arecanut dust	4.8	53.0	295.0	0.18	2.32
Mimosa extract	4.7	25.0	95.0	0.26	0.80

The areca tannins have a lower acid/salt ratio. As a consequence, they produce a mellower type of leather. Being richly endowed with non–tans (salt), they show quicker rate of diffusion through leather. The hydrothermal stability of leather tanned by areca tannins is good. *Chogaru* liquor is not sufficiently good for tanning leather as the whole nut tannins, but it can still be utilized successfully for a wide range of leathers (Selvarangan, 1955; Govindarajan, 1968).

The above studies have shown that the condensed tannins of arecanut, tan leather satisfactorily except for the colour. Pilot plant studies (Anonymous, 1978c) showed further that areca tannin extracted by seeping in water for four days (1 part nut: 4 parts water) has a pH of about 5.3 and that total solubles come to about 7.5 per cent containing tans to non–tans in about equal proportions. This material can be used as such or in blend with myrob (1:1 or 1:2 ratio) for retaining chrome leather. Tannins extracted from defatted arecanut were of better quality. The percentage recovery of total solubles was also higher in this case.

Other uses for which areca tannins have been tested, has been as an adhesive in plyboard manufacture, (Narayanamurthi and Gupta, 1963; Rao, 1977) and as a textile dye (Anonymous, 1961, 1962b, 1963, 1964). Studies carried out in Delhi University, Department of Chemistry showed that *chogaru* gave a satisfactory brown shade to cotton, that was fast to acid, alkali and washing tests. *Chogaru* was also found to be a good dye for wool and paper. It could produce a variety of shades with metallic salts as mordants (Anonymous, 1964). During the processing of raw nuts, the leucoanthocyanidins get polymerised into leucocyanidin which is found in *chogaru*. These polymerized compounds act as good inhibitors in the oxidation of sodium sulphate. However, the *chogaru* liquor was not an effective corrosion inhibitor. The Delhi University work has suggested the possibility of using leucocyanidin in the purification of sugar juice because of its action as an antioxidant (Anonymous, 1964).

Narayanamurthi and Gupta (1963) and Rao (1977) used *chogaru* for preparing tannin–formaldehyde adhesives used for preparing plyboards. They tested a number of formulations on several species of timber for the glue–adhesion properties and found that *chogaru* possesses glue–adhesion strength in the dry and wet conditions according to IS:303–1975 specification for plywood for general purposes.

Another possible use of areca tannins has been as a food colour. They become red at an alkaline pH, and with the increasing prohibition of the use of synthetic food colours, this possibility assumes greater importance. Two approaches are possible in this, (1) preparing and using natural pigments as a safe food colouring agent and (2) rendering the food colour unabsorbable in the intestine by combining it with a macromolecular matrix. This line of study has been taken up in the Department of Chemical Technology, University of Bombay by Rege and Garde, (Garde, 1982). According to this work, the areca polyphenolics can be fractionated as monomers and dimers into one fraction and the polymers (highly polymerised substances–HPS) into another fraction. The HPS fraction is red in colour. The results obtained so far have been promising. These workers have taken up studies for optimizing the conditions for maximizing the yield of HPS, its purification for varying the extent of polymerization and for determining the effect of various environmental conditions on the yield and stability of the HPS fraction.

2. Fats

The nut contains 8–12 per cent fat. Fat from arecanut can be extracted by solvent extraction using hexane. Improper storage of raw nuts over prolonged periods lead to lipolysis. The analytical characteristics of areca fat are given in Table 10.3.

The biglyceride distribution in the fat appears to be unusual and does not follow the predicted distribution pattern (Anonymous, 1978d; Shah, 1980).

Broadly, areca fat has comparable characteristics with hydrogenated coconut oil. It contains both saturated and unsaturated fatty acids. Areca fat can be made edible by refining it using an alkali (Anonymous, 1978d). The refined areca fat is harder than cocoa butter, and even better, due to its high myristic acid content. The fat could be softened by fractional crystallization using hexane 25°C and randomisation using sodium methoxide which gave products desirable for use as confectionery fat. Simple blending of areca fat with butter fat at 3:1 ratio followed by inter esterification of areca fat and cocoa fat at 1:1 ratio gave good

products acceptable in confectioneries. Limited studies show that areca fat can be used as an extender of cocoa butter for various purposes. Further, sweets, savouries and biscuits prepared from refined areca fat were as good as those prepared from *vanaspati* fat (Reddy et al., 1976).

Table 10.3. *Analytical characteristics of areca fat*

Characteristics	Value (range)
Free fatty acids	Highly variable
Acid value (A. V.)	Highly variable
Saponification value (S. V.)	222–235
Iodine value (I. V.)	17–26
Melting point (°C)	38–42
Slip point (°C)	36–39
Saturated fatty acids (%)	
Myristic acid	50
Lauric acid	18
Palmitic acid	14
Capric acid	1
Unsaturated fatty acids (%)	
G S_3 (trisaturated)	60.2
G S_2U (monounsaturated disaturated)	22.0
G SU_2 (disaturated monounsaturated)	17.7
G U_3 (triunsaturated)	0.1

In several native systems of medicine, arecanut is assumed to provide several beneficial effects on digestion, strengthening of gums and stopping of bleeding etc. Because of these, some work on these lines has been taken up by Rege and Garde in Bombay University (Garde, 1982) for preparing chewing gum and tooth paste based on arecanut. Encouraging results have been obtained in preparing chewing gum and tooth paste using arecanut extract.

Scented *supari* has been prepared using both defatted and detannined arecanut. Normally, for extracting tannins and fats, the nuts have to be crushed before extracting them with water or hexane, and the crushing and extraction make the arecanut somewhat softened, and this has been sometimes found to adversely affect the consumer acceptability of such scented *supari*. However, this seemed to become an adverse factor only in the case of detannined arecanut and not in defattened arecanut. It is necessary to conduct some more studies on consumer acceptability and product improvement.

It would thus appear that with the present level of supply and market price, and our present state of knowledge on product development with the nut constituents, it would not be economical to use arecanut solely for extracting just one constituent of the nut. It may be feasible to develop a system by which the various constituents can be progressively extracted in a modular pattern with each of them put to different uses.

II. Arecanut husk

It is the outer cover of the areca fruit. It constitutes 60–80 per cent of the total volume and weight of the fruits (fresh weight basis). About 1,00,000 tonnes of dry husk are estimated to be available annually in India alone. It is now being largely wasted except for being used as an inferior fuel and mulch. It was used in Indochina and the Philippines for tooth brushes (Brown, 1952; Anonymous, 1958).

The biochemistry and physical properties of the husk have been studied by Baruah, Raghavan and Murthy, (1957) and at the Jute Technological Research Laboratory (JTRL), Calcutta (Anonymous, 1973). The husk can be anatomically divided into three zones, *viz.*, (1) the outer epidermal layer covered with the cuticle; (2) the middle layer which encloses the fibres; and (3) the hard and stony inner layer adpressed to the nut.

1. Fibre

The husk fibres are predominantly composed of cellulose with varying proportions of hemicellulose, lignin, pectin and protopectin. The fibres adjoining the inner layer are irregularly lignified group of cells called 'hard fibres' and in the portion of the middle layer below the outermost layer are soft fibres. The total hemicellulose content varies with development and maturity, the mature husk containing less hemicellulose than immature ones. The lignin content proportionately increases with development till maturity is reached. The biochemical constituents of husk are given in Table 10.4 (Baruah et al., 1957; Govindarajan, 1968).

Table 10.4. *Biochemical constituents of husk*

Constituents	Percentage (range)
Pectin	1.5– 3.6
Protopectin	1.5– 2.1
Hemicellulose	35.0–64.8
Lignin	13.0–26.0
Furfuraldehyde	18.8
Ash	4.4

At the Jute Technological Research Laboratory, Calcutta, the physical properties of areca fibre were studied and compared with those of jute (Anonymous, 1973). The average filament length of areca husk fibre was too short (2.4 cm; C. V. 30%) compared to the filament in jute yarn (68 cm; C.V. 75%). Their tenacity, fineness, and textural and torsional rigidity were also studied. The areca husk fibre consists mostly of two types of filaments, very coarse and very fine. The coarse ones are about 10 times as coarse as the jute ones,and the fine ones are similar to jute fibre. Spinning trials with standard jute and coir machinery were not quite successful. However they prepared non-woven fabric using synthetic rubber latex as bonding agent at 8 per cent concentration. Based on the various tests, the JTRL proposed that areca husk fibre could be used for making such items as thick boards, fluffy cushions and non-woven fabrics (Ghosh, Sinha and Bandopadhyay, 1975).

Retting trials for extracting the fibre have shown that perceptible softening could be obtained after three weeks soaking (Prabhu, G. N. 1978, personal communication). The fibres can be extracted later by beating with a mallet. Baruah et al., (1957) found that pectinolytic bacteria were more effective than hydrolytic agents for rapid softening of husk and also that the quality and nature of the fibres depended mainly on cellulose content and non-cellulose encrustations.

2. Hard boards and plastics

Several studies have been carried out, particularly in the Forest Research Institute, (FRI) Dehra Dun to see if arecanut husk could be utilized for preparing hard boards and plastics (Narayanamurthi, 1957; Narayanamurthi and Singh, 1964).

Narayanamurthi, Ranganathan and George (1947) studied the preparation of hard boards from areca husk by Asplund process. Insulation and hard boards of satisfactory quality were prepared by a process of defibration or hydrolysis with weak acid or alkali at the Forest Research Institute, Dehra Dun (Anonymous, 1952). The boards compared favourably with standard foreign boards like Masonite in respect of thermal conductivity, thickness, density and strength properties, but water absorption and swelling properties were not satisfactory.

Narayanamurthi and Singh (1961a, 1961b, 1964) developed several processes for preparing fibre boards and plastic boards from husk. Simple treatments of the husk followed by oil tempering with cashew nut shell liquid (CNSL), and adding furfural and aniline, to the mass, gave boards of increased strength and less water absorption. The preparation of plastics by thermal condensation with

20 per cent sodium thiosulphate and furfural was found to be the best method due to condensation of colloidal sulphur. The boards compared favourably with oil tempered hard boards and filled phenolic plastics, though modulus of elasticity was slightly lower than that of typical PF plastics. The boards had good microbial resistance and better properties than those made from bamboo. Hard boards with satisfactory strength properties could be also made by chemical pulping of the husk and by using cold and hot setting adhesives.

Plastic and hard boards of satisfactory strength and water repellant properties can be made from areca husk; but so far, these processes have not been commercially exploited. However, their cost–economics also require to be worked out. The insulation wool produced by beating air–dry husk with wooden mallet compares favourably in respect to thermal conductivity, moisture content, density of packing etc, with standard products like Palcowool, defibrated teak bark and granulated cork (Anonymous, 1952; Raghavan and Baruah, 1957). Its usefulness in thermal insulations, accoustical correction, packing etc. appears to be promising.

Husk can be processed into insulating wool and felt in admixture with jute and caddles (Raghavan and Baruah, 1957). Soft cushion pads made from spongy fibrous mass obtained by boiling the green husk with 5 per cent NaOH solution for 30 min and defibration, compared well with cushion pads made with imported material and that these could be used as packaging for books, for making cushioned envelopes, soft boards etc. (Anonymous, 1962a, 1962b).

3. Pulping and paper boards

The first work on preparing paper from arecanut husk was carried out during early twenties (Anonymous, 1922). Since then during the fifties and sixties, more work was done on this aspect (Singh and Guha, 1960; Subramanian and Govindarajan, 1962; Guha et al., 1963). Broadly, these have shown that brown wrapping papers in satisfactory yields and quality could be prepared from blends of arecanut pulp and bamboo or banana pseudostem pulp.

In subsequent studies carried out at the FRI, Dehra Dun, sulphate pulps prepared from digesting husk, using 13.5–18.6 per cent, chemicals at 170°C for 4 hr, had fibre length of 0.96 mm, fibre diameter of 0.0196 mm, hot water solubility of 19.7 per cent, and lignin 30 per cent and the pulp yield was 40.4–57.5 per cent (Anonymous, 1976b). The strength properties were not satisfactory for

producing kraft wrapping paper, but brown wrapping paper with improved properties could be prepared when mixed with jute or bamboo pulp (Table 10.5; Singh and Guha, 1960).

Table 10.5. *Properties of arecanut husk pulp sheets mixed with jute and bamboo pulps*

Properties	Arecanut husk pulp sheets	
	Mixed with jute sticks pulp (40–80%)	Mixed with bamboo pulp (40–80%)
Breaking length in m	6220–8448	4650–5000
Tear factor	92–103	124–143
Burst factor	32.3–43.1	27.5–32.1
Folding endurance	131–346	68–255

The studies carried out at the CFTRI, Mysore (Anonymous, 1962a; Subramanian and Govindarajan, 1962) in collaboration with Mandya National Paper Mills showed that areca husk when chemically pulped by soda cooking process with 17.5 per cent of NaOH in the ratio 5:1 at 170° C for 2 hr and beaten for $1\frac{1}{2}$ hr in edge runner, gave pulp material having properties of ordinary kraft paper. However, bleaching of pulp could not be done with sulphite process, but lighter and brighter pulp was achieved. Paper produced from mixing of beaten banana stem pulp 25 per cent to areca husk pulp, was found to provide equal strength of ordinary kraft paper (Table 10.6).

Table 10.6. *Properties of paper produced from areca husk pulp mixing with banana stem pulp (25%)*

Properties	Paper from areca husk pulp mixed with 25% banana stem pulp	Ordinary kraft paper
Breaking length in m	3133	3779
Tear factor	76.5	77.0
Burst factor	19.1	17.5
Basic weight (g/m^2)	73	70

In 1975, plant level studies carried out at the Punalur Paper Mills Limited, Kerala (Anonymous, 1974, 1976a) confirmed the earlier finding that areca husk could be pulped chemically at 170°C for 4 hr giving 45–50 per cent yield. The pulp was short fibred and could produce paper of only low bursting strength and break factor. When the areca pulp was blended with bamboo pulp (3:1 ratio), the kraft paper made with it possessed comparable physical properties of paper made

with pure bamboo pulp. Guha et al., (1963) (*also* Anonymous, 1977b) have described a pilot plant for producing low grade wrapping paper using a mixture of areca pulp (60%) and bamboo pulp (40%). All the studies have shown that it is difficult to bleach the paper made out of areca husk pulp.

The data presented here would indicate that while kraft paper of acceptable quality can be prepared from areca husk (Table 10.6) the high cost of transporting husk to the factory and the high amounts of chemicals required for digesting the husk are factors to be reckoned against it in exploiting commercially.

4. Other possible uses

Areca husk can be a good source of furfural. When distilled with acid at high pressure and temperature, the husk yielded 5.5 per cent furfural (Anonymous, 1952; Singh, 1956). The husk contains about 18 per cent furfuraldehyde (Raghavan and Baruah, 1957).

Preliminary investigations carried out at the Indian Drugs Research Laboratory, Pune, (Anonymous, 1981) revealed that areca husk upon acid hydrolysis followed by neutralisation and precipitation in ethanol could yield 2–3 per cent xylose. Xylose is a monosaccharide and xyletol derived from xylose by hydrogenation is sweet.

Possibilities of producing activated carbon from arecanut husk have been investigated by Latif and Khundkar (1952) and Chowdhury, Chakravarthy and Bhattacharya (1971). The residue of areca husk after extracting xylose can be used for producing activated carbon of good quality. The yield is about 25–28 per cent.

Possibilities exist also for using areca husk as a manure. It contains 1.0–1.1 per cent N_2, 0.4–0.5 per cent P_2O_5 and 1.0–1.5 per cent K_2O. Hence, it can form good organic manure if properly composted. The total quantity of 1,00,000 tonnes of dry husk would give, if collected and composted, about 1000 tonnes N_2, 500 tonnes, P_2O_5 and 1000 tonnes K_2O (Biddappa, 1960). However, the husk is very resistant to microbial degradation because of the presence of ligno–cellulose.

III. Leaf sheath

Leaf sheath is yet another raw material obtained from the arecanut palm. In a year, a palm sheds 5–6 leaves. About 1,000 million leaf sheaths weighing

about 2,33,000 tonnes are available annually in India alone (Bavappa and Murthy, 1960; Menon, Annamalai and Nayar, 1982).

The sheaths measure 75–85 cm long and 35–40 cm wide at the centre and 15–20 cm wide at the stalk end. Freshly fallen sheaths contain 55–60 per cent moisture. This reduces to 11–16 per cent after drying in the open, under shade for 5–6 days. The sheath of an adult palm shows a concavity in the centre. The leaf sheath is heterogenous in structure, composition and appearance and these create problems as well as widen the scope for product development. The outer surface of the sheath is greenish or brown, waxy and tough, while the inner surface is creamy in colour and has a natural glossy finish. The constituents of the leaf sheaths are cellulose–43 per cent; crude fibre–33 per cent and ash–5 per cent. From the manurial point of view, they contain N_2–0.7 per cent; P_2O_5–0.3 per cent and K_2O–1.0 per cent (Biddappa, 1960). In certain regions of Kerala, leaf sheath is also used as a cattle feed.

In recent years, trials have shown that quality pulp suitable for making packing paper boards can be also obtained from areca leaf sheath. Laboratory level testing on pulping of areca sheath by digestion by sulphite process at 162°C for $3\frac{1}{2}$ hr gave a pulp yield of 36–40 per cent with burst factor of 50 and tear factor 113 and breaking length of 6200 m. The pulp in admixture with other pulp can be use for making packing paper boards (Narayanamurthi, 1957; Subramanian and Govindarajan, 1962).

Taking a cue from the numerous traditional uses to which areca leaf sheaths have been and are being used [*eg.*, caps (Fig. 10.1) and hats for farm workers, containers and packing cases for collecting and transporting materials at home like toddy, fish etc. and scoop for watering garden] throughout south and south east Asia, and based on its mechanical properties, a series of studies were initiated and sponsored by the CPCRI Regional Station, Vittal to develop active economic uses for the material. The process consists essentially of flattening the sheath under heat and pressure and then utilizing it for making various products (Menon et al., 1982).

1. Throw-away cups and plates

The flexibility and pliability of the sheath when it is wet makes it a good material for heat moulding. The CFTRI, Mysore has developed a machine for making cups (Fig. 10.2) and throw-away plates which can substitute the paper plates now being used (Anonymous, 1977a, 1978b, 1980). The machine is

manually operated by leg and is capable of producing 100 cups per hour with one skilled operator and helper. For this, the leaf sheath is subjected to 158°C temperature for 10 seconds in the machine for moulding. Such cups (Fig. 10.3A) and plates (Fig. 10.3B) are already being produced in a small scale unit in Karnataka.

2. Leaf sheath plyboards

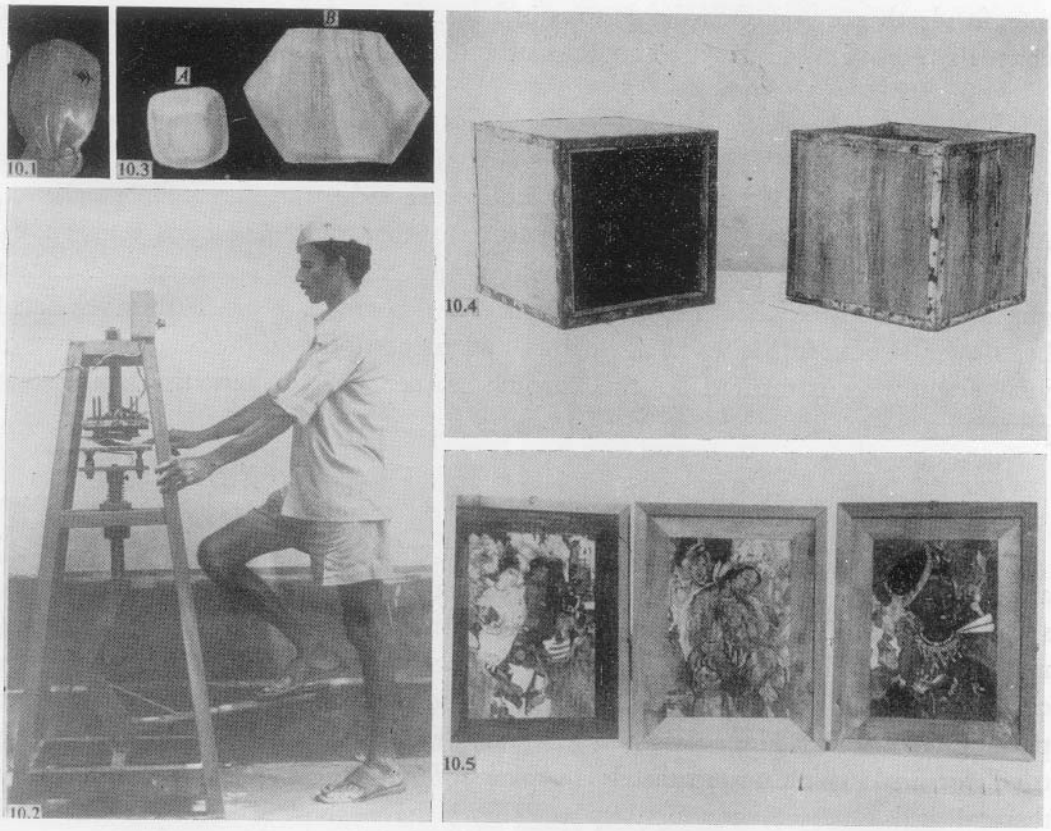
The tensile strength though moderate and the flat surface of the processed sheath make it a suitable material for preparing plyboards (Annamalai and Nayar, 1982). As the sheaths are weak across the grain direction, they are strengthened by interposing one plywood veneer between two plies of sheaths and gluing them to make 3-ply boards.

Studies on glue adhesion properties of the boards (Annamalai, Menon and Nayar, 1982) have shown that plyboards prepared using cold setting/hot setting urea formaldehyde (UF) resin as glue, extended with tamarind seed powder (TSP) or deoiled sal meal upto 15 per cent and with any ordinary 1.5 mm thick wood veneer as core ply and pressed (at 4 kg/cm^2 pressure for 16 hr for cold setting glue and 14kg/cm^2 pressure at 95–100°C temperature for 7–10 min for hot setting glue) gave satisfactory results. The glue shear strength of the boards (4.2 mm thick) was 45–55 kg (average) in dry state and 12–16 kg (in wet state after 24 hr soaking in water at 28°C) and the boards could withstand delamination upto 6 days when soaked in water for seven days. These plyboards do not meet fully the ISI requirements of tea chest plywood, but they are superior in wet glue shear strength than most non–ISI grade plyboards available in the market.

Hence, tea chest and packing cases made of areca leaf sheath plyboards can be put to most of the uses for which plyboards are presently used. These boards further possess better impact strength and double the flexibility over the 3–plywood boards. These are properties, that are most desired for use in preparing suitcases.

A few trials carried out through the courtesy of a leading tea agent in Cochin, Kerala with tea chest made from areca leaf sheath plyboards (Fig. 10.4) for transporting tea from Kerala to north India and even to London after storing tea for three months were successful. Such tea chests not only withstood the rigours of long distance transport, but the quality of tea also remained unaffected. More than threefourths of the tea chests made in India are produced from non-ISI grade plyboards produced by cottage and small scale industries. Even if areca sheath

plyboards are used to meet half of the requirements, the saving of softwood timber that will be brought about will be a significant gain in view of the increasing scarcity of timber in India.



Figs. 10.1—10.5 Items made out of areca leaf sheath and a machine for making cups and plates from areca leaf sheath. *Fig. 10.1 Cap; Fig. 10.2 A machine for making cups and plates from areca leaf sheath; Fig. 10.3A Throw-away cup; Fig. 10.3B Throw-away plate; Fig. 10.4 Tea chests; Fig. 10.5 Picture mounts.*

3. Decorative veneer panels and picture mounts

Aesthetically attractive and imaginative novelties can be made from areca leaf sheaths taking advantage of the natural colour and grain variations on the surface. For this, the sheath surface is given a finish in varnish or french polish. They make beautiful picture mounts (Fig. 10.5) or decorative panels. The dark and white faces of the outer and inner surfaces of the sheath can be exploited to prepare decorative panels of wooden almirahs (Fig. 10.6) and teapoys (Fig. 10.7) (Menon et al., 1982)

4. House sandals

The firmness combined with the easy yielding of the sheath and its ability to absorb moisture in the form of sweat suggest its usefulness as a cheap substitute for leather or cardboard sole tops in house chappals and cheap summer wear chappals (Fig. 10.8) in the drier regions of India and elsewhere.

5. Gin washers

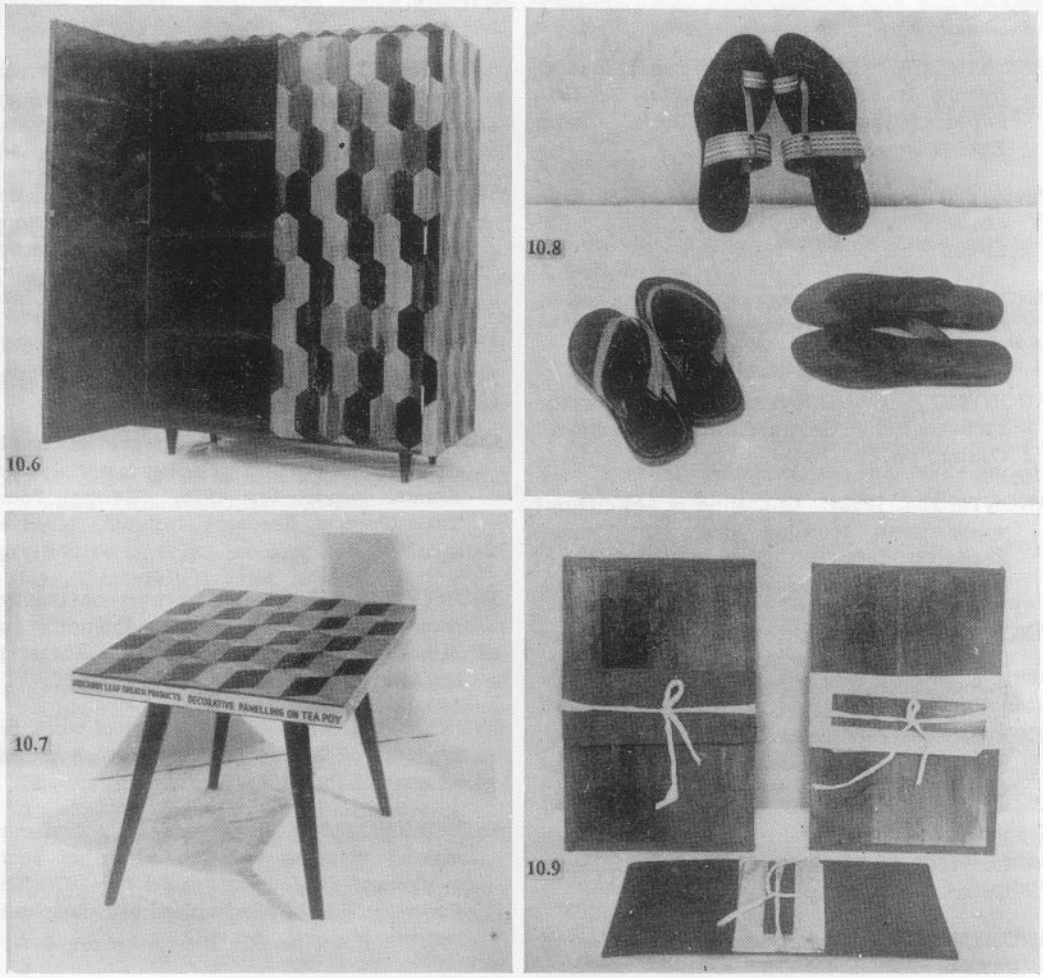
The trials carried out at Ahmedabad Textile Industries Research Association, Ahmedabad and Cotton Technological Research Laboratory, Bombay (Anonymous, 1978 a; Menon et al., 1982) with cotton ginning rolls made of areca leaf sheath gin washers showed that their performance was not satisfactory as they generated heat faster, produced higher trash in lints and reduced the strength and out put of yarn slightly as compared to the chrome leather gin washers that are used at present.

6. Other possible applications

Brief cases, bags, spectacle cases, tea and coffee trays, file boards (Fig. 10.9) and many other fancy and utility products have been prepared out of areca leaf sheaths. Possibilities for using the sheaths in the manufacture of match boxes, match sticks and paper boards for packing also appear to be promising. The corky feel and lightness of the sheath make it possible to convert the sheaths into packing wool for packing glassware and such fragile articles. Sheaths can be also tried for making lining materials in place of cork sheets. Tests conducted for thermal and electrical conductivity of sheath have shown that it could enter manufacturing fields where thermal and electrical insulations are needed.

IV. Arecanut stem and leaf

Arecanut stem forms a useful building material in the villages and it is widely used throughout south and south–east Asia for a variety of construction purposes. Because of its hardness and its golden yellow colour, the timber can be used for making a variety of elegant utility articles (Bavappa and Murthy, 1960). Stationery articles like rulers, shelves, waste paper baskets, etc. made of the stem are both durable and attractive. In south Asia, the stem after sharpening is used for husking coconuts. Nails made of areca stem are widely used in furniture industry. Hollow stems lend themselves into drainage and irrigation pipes in the villages.



Figs. 10.6—10.9 Useful items made out of areca leaf sheath.
Fig. 10.6—10.7 Decorative panels of wooden almirah and teapoy;
Fig. 10.8 Chappals and sandals with areca leaf sheath sole tops;
Fig. 10.9 File boards and flaps made out of areca leaf sheath.

The leaves are good source of organic manure. About 3,40,000 tonnes are estimated to be available annually in India alone. Their approximate composition is N_2–0.94 per cent; P_2O_5–0.096 per cent and K_2O–1.00 per cent (Biddappa, 1960).

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11

MARKETING

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In commodities like arecanut where production is concentrated in a few states and consumption spread all over the country, the efficiency of marketing system assumes great importance. Operations involved in the movement of arecanut from the producers to the consumers could be grouped under two main phases. In the first phase called 'assembling', producers themselves or the itinerant merchants bring the produce to the assembling centres and in the next phase described as 'distribution', subsequent movement of the produce from the assembling centres to the consumers takes place. Since there are many intermediaries in the marketing system, producers normally get only a reduced share of the consumer's price depending on the distance between the assembling and distributing centres, various market charges and margins, and season of disposal.

I. Types of markets

There are no exclusive markets for the sale of arecanut in the country. As in the case of other agricultural crops, arecanut also forms one of the commodities handled in a particular market. There are primary, secondary and terminal markets dealing in agricultural commodities including arecanut.

The primary markets are at the village level and generally held once in a week on a fixed day. They are usually located in the interior parts and serve the needs of villagers. The secondary markets are regular wholesale markets held daily at fixed places and are usually situated in the district or *tehsil* headquarters, and important trade centres. Both assembling and distribution take place in these markets. The third type called terminal markets are those in which the produce is assembled for further distribution for intra and inter-state trades and for exports. This type of markets are common in the trade of processed arecanut, but do not exist for ripe arecanut (Anonymous, 1964).

II. Assembling and distribution

Arecanut is marketed as unhusked whole fruit, dehusked and dried nut, boiled and dried whole kernel or their cuts. Nearly $\frac{1}{3}$ of the total arecanut production in India reaches the consumers as ripe fruit and the remaining in the processed form.

1. Unhusked whole arecanut

Marketing of semi-ripe, fully ripe or fermented arecanut is of commercial importance only in Kerala, Assam and West Bengal and practically unknown in Karnataka and other states. In Kerala where areca growers generally do not undertake processing, about 30 per cent of the produce is marketed after harvest, either as semi-ripe or fully ripe whole arecanut in the nearest primary markets. This is mainly used for local consumption. A small part of the produce is stored in the form of fermented arecanut *(neetadakka)* for sale in the off-season. About 35-40 per cent of the produce are assembled in the primary market by the growers, nearly 50 per cent by the itinerant merchants and the remaining by a few processors and co-operative societies. Both growers and itinerant merchants sell the produce to the processors in the assembling markets for conversion into whole dry arecanut *(kottadakka)* or split *(parcha)* (Anonymous, 1961).

About 90 per cent of the crop is consumed locally in Assam in the form of semi-ripe, fully ripe or fermented arecanut. The assembling and distribution of arecanut take place mainly through hundreds of primary markets or *hats* located all over the state. In these markets the growers themselves assemble nearly 60 per cent of the produce, while the remaining 40 per cent is assembled by other agencies such as village merchants, itinerant merchants and processors. In the primary markets arecanut is sold by the growers to the local buyers on retail basis or to their agents who purchase and sell it to shop keepers for retail distribution. Processors purchase ripe arecanut for conversion into whole *(gota supari)* or split *(kata supari)* dry arecanut. Besides the primary markets, the distribution to some extent also takes place in the wholesale markets like Gauhati, Nowgong etc. mainly through the commission agents or wholesale merchants (Shamanna, 1958; Anonymous, 1961). The assembling and distribution of arecanut in West Bengal is done through a large number of periodical markets or *hats* where the growers themselves take the produce and sell it to the local consumers directly.

Bulk of the production in Maharashtra is in the form of ripe nut. The general practice followed in the state is to strip the outer skin of the fruit from

three sides and dry partially. Afterwards the produce is sold to the middlemen and commission agents who take up dehusking, drying and sorting. The important assembling and distributing market in Maharashtra is Bombay.

Arecanut crop in Goa is harvested only in ripe stage. About 92 per cent of the production is converted into *chali* and the remaining consumed as fresh nut or preserved in water for use in the off-season. Most of the small growers invariably take loan from commission agents and village merchants on the understanding that the produce after harvest will be sold to them at the prevailing market price. Commission agents and village merchants get the necessary advance for this purpose from the wholesale merchants (Anonymous, 1966).

2. Processed arecanut

Marketing of processed produce is more popular and better organised in most of the producing states. In Karnataka, 95 per cent of the harvested crop is converted into different types of processed (boiled or unboiled) arecanut. The processing is done mainly by the growers in *Malnad* tract and in *Maidan* region it is done by the agents who take the garden on lease. The important assembling markets in Karnataka are Mangalore, Shimoga, Sirsi, Sagar, Siddapur and Kumta. The share of the growers in the assembling of the produce has been estimated at 60 per cent. The itinerant merchants account for about 10–15 per cent of the total quantity assembled and the remaining quantity by the co-operative societies. Much of the wholesale distribution is attended to by commission agents, and wholesale merchants. Retail distribution is attended to by the agencies like growers, village merchants, commission agents, wholesale merchants and shop keepers or retailers. Among these the last mentioned agency is the most important, next to growers (Anonymous, 1961).

In Kerala, about 70 per cent of the production is converted into processed arecanut. It consists of both unboiled and boiled types. It is estimated that 70–75 per cent of the processed arecanut is produced by the professional processors and assembled by them. The remaining portion is assembled by the growers and itinerant merchants. Unlike Karnataka, the role of co-operatives in Kerala in the assembling and distribution of processed arecanut is insignificant. The important assembling and distributing markets in Kerala for processed arecanut are Palai, Ponkunnam, Alleppey, Cochin, Trichur and Kasaragod (Anonymous, 1961).

In Assam, only 10 per cent of the production is converted into processed arecanut. The main assembling markets are Gauhati and Dhubri and to some

extent Shillong. About 90 per cent of the produce is assembled by the processors. The share of the wholesale merchants and co-operative societies in assembling of arecanut is insignificant (Anonymous, 1961).

In Tamil Nadu, about 40 per cent of the crop is marketed at mature stage for preparing special types of processed arecanut. In Mettupalayam area, sun dried nut is prepared. The processing methods followed to prepare *kalipak* are similar to those in Kerala. Assembling is mostly done at Madras and commission agents and brokers operate in this market. For local distribution, wholesale merchants contact commission agents through brokers and obtain their requirements on credit basis. Further distribution is carried out through retail shop keepers and *panwalas*.

III. Marketing practices

In Kerala, the crop is sold mainly as tender arecanut for the preparation of *kaliadakka* (boiled and coloured types). The common practice is to remove the husk and sell the produce as raw arecanut. Since the nuts are perishable in this form, the producers and itinerant merchants are often compelled to sell them to the processors or to their agencies immediately. Sales are effected by open negotiations between the seller and the buyer either in the nearby market or in the processors' premises, based on weight. After settling the price, the goods are delivered on the spot and payment is received in cash. In the case of ripe arecanut the same method of sale is followed but the price is settled based on the number of nuts. Sale of fermented arecanut is also effected on the basis of number. As almost the entire production of ripe arecanut is locally consumed, there is no inter-state trade in this case (Anonymous, 1961).

In Assam, the ripe nuts are assembled in heaps on the scheduled market days by the various marketing agencies and individual lots are sold by open bargaining between the buyers and the sellers after inspection of the samples. Payment is immediately made in cash, based on the number of arecanuts. When sales are effected in the premises of the gardens, growers need not pay any expense but when disposed off in nearby villages, a market toll which varies from place to place has to be paid. Although major portion is locally consumed, small quantities are sold for use in neighbouring states of Manipur, Tripura etc. (Anonymous, 1961).

In the important arecanut markets like Mangalore and Sirsi in Karnataka, the commission agents conduct auction and arrange for the sale of the produce

received from the growers. The agents store the produce in their godown without any charge and also advance loans to the customers on the security of the produce, pending disposal. The buyers are mostly local merchants who after taking delivery of the produce despatch it to different consuming centres. The marketing practices are regulated by the local market committees and auctions are conducted in the presence of officials.

In Kerala, unboiled varieties like *chali* and *parcha* prepared in Nedumangad and other parts of Trivandrum district and in the Kasaragod Taluk of Cannanore district are marketed mainly through Alleppey and Mangalore markets. Boiled, coloured and dried types prepared in Pazhanji, Chalakudi, Kumaranellur and Thalakkadathur and to some extent in Tirur, Calicut and Perambra are assembled and distributed mainly through Trichur and Calicut markets. From some of the processing centres like Pazhanji and Chalakudi, *choor* is dispatched to Mangalore and Bangarapet in Karnataka. *Nayampak* produced in Palai and Ponkunnam are despatched to Madurai and Virudhunagar and *ottavettu* and *iylon* produced in Tirur and Thalakkadathur are sent to Panrutti, Vellore and Madras, all in Tamil Nadu (Anonymous, 1961).

The centres of production (Fig. 11.1) and consumption of different trade types of ripe and processed arecanut are given in Table 11.1.

The chief agencies engaged in the retail distribution of processed arecanut are the provisional merchants and shop keepers operating in various cities, towns and village markets. To a small extent *pan* shop keepers are also involved in retail distribution. These retail agencies purchase their requirements from wholesale merchants in the nearest market. Retail distributors incur expenditure on transportation of processed arecanut from wholesale markets and also for sorting out and cutting nuts into pieces.

IV. Marketing finance

1. Credit to farmers

Arecanut growers with small holdings are anxious to sell their produce early without waiting for the price increase. Though they get financial assistance from any one of the four sources *viz.*, commercial bank, co-operative societies, commission agents and itinerant merchants, owing to cumbersome procedure to obtain credit from financing institutions, many of the farmers take loans from processors and local traders much in advance of the harvesting season and get themselves bound to sell their produce to the traders. The rates of interest

Table 11.1. *Trade types and varieties of arecanut and centres of production and consumption*

Trade names	Method of preparation	Important grades arranged in order of quality (in trade)	Main centres of production	Main centres of consumption
RIPE ARECANUT:				
Adaka	Fresh ripe areca fruit	–	Kerala, Karnataka, Assam, West Bengal	Kerala, Assam and some areas of Karnataka
Pukka Tamul	Fresh semi-ripe areca fruit	–		
Kacha Tamul		–		
Neetadakka	Ripe areca fruit stored in water	–	Kerala	Kerala (in off season)
Bura Tamul	Ripe areca fruit stored in pits	–	Assam	Assam (in off season)
RIPE DRIED ARECANUT:				
Chali supari *Kottadakka* *Kottapakku*	Ripe areca fruit dried and husked	*Moti, Srivardhan, Jamnagar, Jini, Chali, Malabar, Koka* (the variety *Choll* is the dried areca fruit stored in husk for an year and then sold in husk)	Dakshina Kannada, Uttara Kannada and Shimoga (Karnataka), Cannanore, Kozhikode, Kottayam, Alleppey, Quilon and Trivandrum (Kerala), Mettupalayam (T. Nadu), Ratnagiri, Colaba (Maharashtra), Assam and West Bengal.	Gujarat, Hyderabad, Madhya Pradesh, Uttar Pradesh, Rajasthan, Delhi, Assam and West Bengal.
Assam kata	Ripe areca fruit cut lengthwise into two, dried and husked.			
PROCESSED GREEN NUTS:				
Nayampak	Green nuts cut breadthwise into two equal bits and dried	*Sithanam, Uduthuram, Vettai*	Trichur, Trivandrum and Kottayam (Kerala)	Southern districts of Tamil Nadu
Iylon	Green nuts cut breadthwise into 1–2 mm. thick sections and dried	*Iylon, Sithanam, Iylon alagu, Iylon vettai*	Kerala state	Southern districts of Tamil Nadu
Unde	Green nuts, husked, boiled whole and dried	*Api, Chikkni, Barda, Gotu*	Uttara Kannada district, Sagar and Sorab Taluks (Karnataka)	North Karnataka, Satara, Sholapur, Kolhapur and Hyderabad
Deshawaram, Ottavettu	Green nuts cut breadthwise into two equal bits, boiled and dried	*Nuli, Pheeton, Rajalu, Vantibette, Gorabalu*	Shimoga, Chickamagalur districts	Karnataka, Tamil Nadn and Andhra states
Naluvettu	Green nuts cut breadthwise into four equal slices, boiled and dried	–	Trichur and Palghat districts (produced in small quantities)	Few markets of the southern districts of Tamil Nadu
Churu	Green nuts cut lengthwise boiled and dried	*Kalichur, Payachur, Vellavi chur*	Kerala state, Hassan Tumkur and Chitaldurg districts of Karnataka state	Tamil Nadu, Andhra and Karnataka states

PROCESSED GREEN NUTS:

Mukkalchur	One longitudinal cut and two or three longitudinal cuts perpendicular to the first direction			
Edachur	Two or three longitudinal cuts and another two or three longitudinal cuts perpendicular to the first direction	*Kalichur Payachur, Vellavi chur*	Kerala state, Hassan, Tumkur and Chitaldurg districts of Karnataka state	Tamil Nadu, Andhra and Karnataka states
Pettichur or *Lavangachur*	Number of longitudinal cuts in one direction and again in direction perpendicular to the first			
Podi (big and small)	Green nuts cut both lengthwise and breadthwise to give bits, boiled and dried	*Kalipodi, Vellavipodi*	Trichur and Palghat districts of Kerala state. Tumkur and Hassan districts of Karnataka state.	Karnataka, Tamil Nadu and Andhra states
Erazel	Green nuts very thinly sliced breadthwise, boiled, coated with *kali* and dried	–	Trichur and Palghat districts	Tamil Nadu
Kettumpadi and *Chalakudi*	Green nuts thinly sliced lengthwise, boiled, coated with *kali* and dried	–	Trichur and Palghat districts	Tamil Nadu
Nirolu	Tender nuts, boiled, sliced breadthwise into slices and dried in sun	–	Hangal taluk and Dharwar district	North Karnataka districts
Scented *supari*	1. Green processed arecanuts cut into small bits, mixed with powdered spices, and flavoured. Copra and sugar crystals also added in few cases.	–	Tamil Nadu and Maharashtra states	Throughout India
	2. Ripe arecanut, softened by steeping in dilute sugar syrup, strongly scented	–	Lucknow and Banaras	Throughout North India

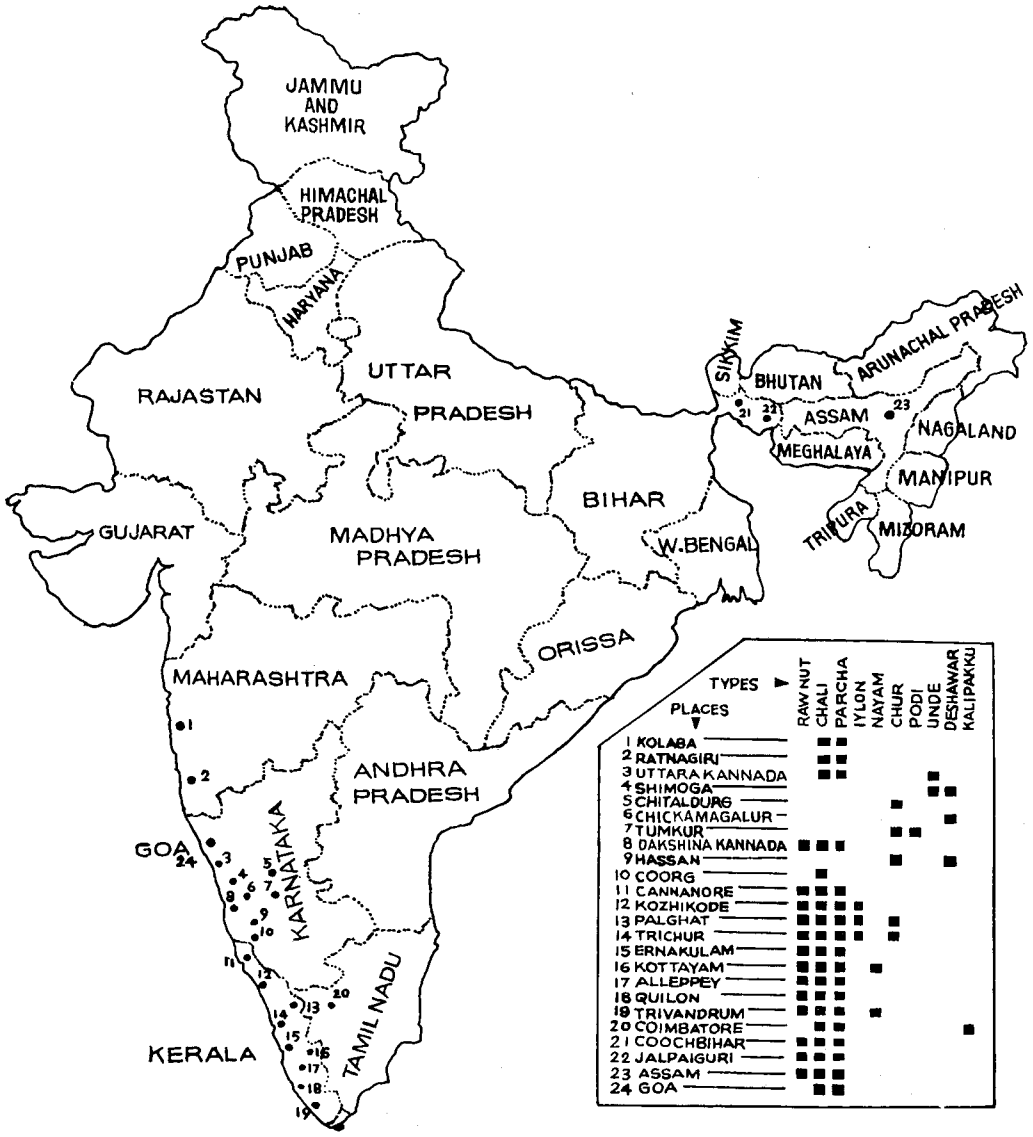

Fig. 11.1 Centres of production of different types of ripe and processed arecanut

charged vary from source to source, the lowest being by the co-operative sector and the highest by the merchants. The processors are able to give loans to the growers as they receive advance from commission agents. So they are also obliged to dispose of the produce to the commission agents on the latter's terms. The growers and processors also get financial assistance from co-operative institutions and commercial banks against the pledge of the crop or the processed produce.

The part played by co-operative institutions in arranging finance to the areca growers is quite insufficient, with the result, they look forward to private agencies to meet their credit requirements (Shamanna, 1960). Arecanut cultivation involve heavy capital investment at different stages and, therefore, long term and medium term loans repayable in easy instalments at low rate of interest is necessary to induce farmers to undertake its cultivation. Credit is required by the growers to purchase fertilisers, insecticides and fungicides, to carry out seasonal operations and to undertake processing and marketing of their produce. The channel for the flow of short term credit is invariably the rural credit societies. According to the controlled credit system introduced in 1936, loans are given to the members by rural credit societies for cultivation expenses on condition that the produce raised with the help of the credit should be delivered to the sales society to which the credit society is affiliated. After realisation of the sale proceeds, the amount due to the credit society is repaid together with the interest and the balance, if any, paid back to the growers (Shamanna, 1963). Some of the Arecanut Co-operative Marketing Societies in Karnataka and Kerala have initiated linking of credit with marketing.

2. Marketing costs and margins

It is estimated by the market studies that the producer's share in the consumer's price is about 70 per cent in the case of unhusked whole arecanut. But in the case of varieties such as *chali, parcha* etc. the growers, share is only 71 per cent while it is 76 per cent in the case of boiled varieties such as *api, batlu, choor erazel* etc. The higher share in the case of boiled varieties is attributed to distribution in the consuming areas nearer to the producing states (Anonymous, 1961).

Most of the wholesale dealers buy processed arecanut as such and distribute the same to the retailers after sorting them out into different grades and qualities to realise additional profits.

In Karnataka, the grower's share in the consumer's price is comparatively higher, since the growers invariably process their produce and market it after preliminary grading.

3. Sales tax

Rates of sales tax on arecanut vary from state to state. Besides sales tax there is central sales tax for inter-state transactions. As some of the states do not buy their requirements directly from the producing states, sales tax on this commodity is levied at two or three points resulting in upto 25 per cent sales tax of the value of the original consignments when it reaches the ultimate consumer.

V. Regulated markets

Karnataka, Kerala, Tamil Nadu and Goa have established regulated markets for arecanut. After regulation, market charges levied have been minimised since in the regulated markets there are no brokerage, charity and other charges (Nambiar, 1979).

In Karnataka, there are 23 regulated markets situated in the important arecanut growing regions *viz.*, Chitaldurg, Challakere, Hiriyur, Shimoga, Sagar, Tumkur, Gubbi, Muliyar, Kunigal, Madhugiri, Pavagada, Sira, Turuvekare, Tarikere, Kadur, Holenarasipur, Chamarajnagar, K.R.Nagar, Kumta, Mangalore, Siddapur, Yellapur and Sirsi. These regulated markets together handle more than 80 per cent of the marketable surpluses of arecanut in the state (Lakshmanachar and Joseph, 1973).

In Kerala although five regulated markets were established in the erstwhile Malabar area during 1956–1968, at present there are only four at Kanhangad, Perambra, Changaramkulam and Vattamkulam. Altogether only less than 10 per cent of the marketable surplus is transacted in these markets.

Forty five regulated markets in Tamil Nadu and two in Goa transact only small percentage of arecanut produced in these states.

VI. Co-operative marketing

Co-operative marketing societies for arecanut have been organised in Karnataka, Kerala, Tamil Nadu and Maharashtra. Marketing societies have also been established in Meghalaya and Union Territory of Goa.

1. Karnataka

In Karnataka, co-operative marketing societies for arecanut have been set up in Dakshina Kannada, Uttara Kannada, Shimoga, Chickamagalur, Coorg, Chitaldurg, Hassan and Tumkur districts. The co-operative societies are fairly successful in their functioning and more than 30 per cent of the marketable surplus in the state is being handled by them. A few marketing societies have arrangements for transporting the produce from the interior places to the head office of the society which is usually situated in the assembling centres. They have also opened a number of collection depots in the important areas of production which are easily accessible to the growers (Lakshmanachar, 1973a).

With the setting up of the South Kanara Agricultural Co-operative Marketing Society Ltd., at Mangalore in 1919 and the Totgars Co-operative Sale Society Ltd., at Sirsi in 1923, co-operative marketing of arecanut gained ground in Karnataka. The erstwhile Indian Central Arecanut Committee financed the Arecanut Co-operative Marketing Society Ltd., Arkalgud and the Tumkur District Areca Marketing Co-operative Society Ltd., Tumkur for the managerial expenses and the Malanad Areca Marketing Co-operative Society Ltd., Shimoga for the popularisation of fungicides for the control of *koleroga* disease. A special feature of the Totgars Co-operative Sale Society Ltd., Sirsi is that it undertakes pooling and grading of the produce of the grower members. There are altogether more than fifteen co-operative marketing societies handling arecanut in Karnataka. These marketing societies exercise a steady influence on the local markets.

All the important marketing societies in the state except the Honnavar Agricultural Produce Co-operative Society Ltd., are now functioning as the agencies of the Central Arecanut Marketing and Processing Co-operative Ltd., Mangalore.

With a view to co-ordinating the activities of the primary arecanut marketing co-operative societies functioning in the state, the Mysore State Arecanut Co-operative Marketing Federation was established in 1958 with headquarters at Shimoga. The Federation received financial assistance and support from the erstwhile Indian Central Arecanut Committee, Calicut. Since the beginning, its performance was not satisfactory and sustained loss continuously during the period 1971-1980. The accumulated loss was 1/6th of the paid up-share capital. The Government of Karnataka, therefore, wound up the Federation in July, 1981.

2. Kerala

Unlike in Karnataka, the arecanut marketing co-operative societies in Kerala, on the whole, have not made much progress. Most of the terminal markets for arecanut produced in Kerala are located outside the state.

The first co-operative marketing society for arecanut in the state was set up in 1943 at Kumaranellur. Subsequently a few more marketing societies were set up and fifteen of them received financial assistance from the erstwhile Indian Central Arecanut Committee, Calicut. Today there are about fourteen co-operative marketing societies functioning in Kerala which handle arecanut. Most of the societies are now working as the agents of the Central Arecanut Marketing and Processing Co-operative Ltd., Mangalore.

The Kerala State Co-operative Marketing Federation was established in 1960 with a view to co-ordinating the activities of all the primary marketing co-operative societies functioning in the state dealing in arecanut and other agricultural commodities (Lakshmanachar, 1971). The Federation had been given financial assistance from the National Co-operative Development Corporation at the instance of the erstwhile Indian Central Arecanut Committee. Besides arecanut, the Federation is now concentrating its activities on other commodities like cashew, cocoa etc.

3. Tamil Nadu, Maharashtra and other states

The co-operative store at Mettupalayam was converted into a co-operative marketing society and a grant-in-aid scheme for marketing of arecanut was sanctioned in 1958 by the erstwhile Indian Central Arecanut Committee, Calicut.

There are about six co-operative marketing societies handling arecanut in Maharashtra. Of these, the Society in Kolaba is now working satisfactorily. The Goa Bagayatdar Sahakari Khareedi and Vikri Society at Ponda is the only co-operative marketing society in Goa for handling arecanut alongwith other produces. Although Assam is one of the major arecanut producing states, no co-operative marketing society has been established to handle arecanut.

4. The Central Arecanut Marketing and Processing Co-operative Limited (CAMPCO)

Research and developmental measures adopted in arecanut led to substantial increase in the production of arecanut in the country and towards the end of 1971 there were indications of an imminent price fall. By the end of 1972 the prices fell by almost half of the 1969-'70 prices. This created panic among the growers of Kerala and Karnataka in particular and the two state governments constituted a committee each to look into the problem. The committee constituted by the Government of Karnataka examined the situation in detail and attributed the reasons for the fall in price to increased production, bleak export potential, lack of alternate uses, market speculation, manipulation by intermediaries, poor holding capacity by the growers and inadequate marketing arrangements. The committee therefore recommended to set up an apex institution to purchase, stock and sell arecanut and also to take up processing, wherever possible (Anonymous, 1973).

In the beginning of 1973, the state governments of Karnataka and Kerala decided to establish jointly a central co-operative institution to improve the

marketing of arecanut. Thus the Central Arecanut Marketing and Processing Co-operative Ltd., (CAMPCO) was established on 11th July, 1973 with its head-quarters at Mangalore. The main objective of the CAMPCO when established, was to procure arecanut from the growers at reasonable price and supply the same to the consumers minimising the number of intermediaries and their margins. The other objectives included undertaking research on diversified and alternative uses of arecanut, distribution of seeds, implements, fertilisers, pesticides and such other agricultural and industrial requirements to the growers (Batra, 1974).

The CAMPCO succeeded in reviving the market within a very short time and by January, 1974 the price was restored to the pre-fall level (Sangameswar, 1978). It could stabilise the market and also narrow down the gap between the price received by the grower and paid by the consumer.

VII. Market intelligence and price fluctuation

1. Dissemination of market price

In the case of arecanut, arrangements for market intelligence in the past were not at all satisfactory. Non-availability of market intelligence to the growers and most of the merchants is one of the main reason responsible for high fluctuations in the price of this commodity in different markets. At present the local authorities in the main producing states have made arrangements through the press and radio for disseminating information on daily and weekly prices, arrivals etc. The Directorate of Cocoa, Arecanut and Spices Development, Calicut is also disseminating market information through its Journal. The Directorate collects and maintains market information not only about the Indian markets but also about the foreign markets in Sri Lanka and Singapore (Nambiar, 1974).

2. Price fluctuation

The price of arecanut varies from market to market on account of differences in variety, grade, colour, maturity, moisture content etc. The price fluctuations are not only due to variation in supply position of the commodity but also due to availability or otherwise of the transport facilities, from one region to the other, efficiency of the market intelligence service, availability of credit and storage facilities and above all the system of marketing free from exploitation.

The price fluctuation in this commodity do not affect the consumption and the elasticity of demand for arecanuts either with reference to price or income is very small (Lakshmanachar and Shenoy, 1964).

i. *Annual price variation*

Arecanut price which showed a steady increase in almost all the markets from 1948–'49 had an unprecedented fall in 1972–'73. However with improvement in the marketing system, the price showed continuous increase since 1974. The price for a few selected types in the important assembling and distributing markets are given in Table 11.2. However, the price has shown differences from market to market and according to the type of product depending on quality (Lakshmanachar and Ravindran, 1965).

ii. *Seasonal price variation*

Since arecanut is a perennial crop, its price generally fluctuates according to seasonal changes (Lakshmanachar and Shamanna, 1965; Sikka and Ravindran, 1973). This phenomenon is more pronounced in respect of *chali*. As the harvesting period of arecanut is from October to March, the fresh nuts arrive in the market from November to May. The stock held from May and sold from October onwards is old and called *choll supari* and fetches premium price over fresh arrivals *(new supari)*. Growers of Dakshina Kannada in Karnataka keep the harvested nuts after drying with husk in tact and send for disposal only by the next October to obtain better price.

VIII. Grading, storage, packing and transportation

1. Grading

The absence of standard grades in arecanut for the different varieties based on scientific analysis is a great handicap in the arecanut trade. Grading of arecanut is done by merchants based on the long standing trade practices which are not always quite precise and scientific.

The Agricultural Marketing Adviser to the Govt. of India fixed grade specifications for whole dried arecanut under 'Agmark' standards during 1952 based on the existing trade practices in the leading arecanut market at Mangalore. But grading did not take place under the Agmark standards in any of the states and no trader applied for certificate of authorisation for grading and packing. These specifications have been revised subsequently (Anonymous, 1961).

In accordance with the recommendations of the Directorate of Marketing and Inspection, two schemes on experimental grading of arecanut in Karnataka and Tamil Nadu were initiated during 1962 and 1963 respectively with the financial assistance from the erstwhile Indian Central Arecanut Committee and the concerned

Table 11.2. *Annual wholesale prices in rupees per quintal of few selected types of arecanut in important assembling and distributing markets (1969–'70 to 1981–'82)*

Year	Unhusked nuts (ripe)	Unboiled wholes				Unboiled cuts and pieces	Boiled and coloured wholes	Boiled and coloured splits	Boiled and coloured slices
	Trichur (Rs. per 100 nuts)	Mangalore	Kozhikode	Silchar	Delhi	Trichur	Sirsi	Shimoga	Trichur
		Choll	*Supari*	*Drynuts*	*Mettu-palayam*	*Iylon*	*Rashi*	*Saraku*	*Erazel*
1969–'70	—	722	532	724	—	1059	583	—	1213
1970–'71	—	795	509	689	—	1197	713	—	1296
1971–'72	41	715	379	621	725	912	673	971	1107
1972–'73	33	522	255	507	540	782	390	662	918
1973–'74	37	530	293	521	475	1052	425	769	1188
1974–'75	44	768	422	706	701	957	578	776	1339
1975–'76	49	846	439	601	817	976	769	937	1427
1976–'77	63	875	498	702	908	1175	749	1195	1519
1977–'78	50	880	431	650	926	1165	733	1316	1616
1978–'79	58	937	532	827	1015	1587	791	1452	1811
1979–'80	85	1256	859	1038	1346	1569	1143	1586	2135
1980–'81	98	1649	1158	1189	1690	1864	1556	1923	2301
1981–'82	111	1802	1207	1220	1954	2020	1736	2199	2421

state governments. In Karnataka three centres (1) Mangalore (for sun dried whole–*chali*), (2) Shimoga (for boiled splits–*deshawaram, choor* etc.) and (3) Sirsi (for boiled whole–*api*) were selected. In Tamil Nadu the centre selected was the Mettupalayam Co-operative Marketing Society (for sun dried whole–*chali).*

The economics of grading as worked out at these centres indicated that grading the produce before selling, fetched a premium of Rs. 30–100 per quintal over the ungraded produce depending on the trade type of arecanut, the terminal market, demand etc.

As a result of the trials at the experimental grading centres, grade standards for sun dried arecanut published as early as in 1952 were reviewed, finalised and published in the Government of India Gazette in 1969 (Table 11.3). Specifications for the boiled and dried arecanut were first drafted, finalised and published in the Government of India Gazette in 1979 (Table 11.4).

Compulsory grading of arecanut under 'Agmark' for export has not yet been introduced although some quantities of arecanut are regularly exported from India. A very nominal quantity (78 tonnes during 1979–'80) of arecanut was only graded under 'Agmark' for internal trade on voluntary basis, during 1979–'80. However over 14,0481 tonnes were graded during 1979–'80 at producers level mostly in Karnataka (at Mangalore, Shimoga and Sirsi) and to a certain extent in Goa and Assam (Lakshmanachar, 1973b).

2. Storage

It has been estimated that about 8–10 per cent of the harvested ripe arecanut is stored in pits or steeped in water for consumption during off–season in Assam and Kerala and to some extent, in West Bengal. Due to improper methods of preservation, the stored ripe nuts emit foul smell. However, the kernel inside is in good condition except for the putrifying smell of the husk infiltrated into it. In Assam, ripe nuts are preserved in pits covered with mud or in running water in streams. Husk of nuts stored in pits gets fungal infection and the white coloured core and the portion between the brown veins of the kernel are damaged to some extent. To overcome the deterioration of ripe nuts in storage, a method of preserving them in a solution of mixed preservatives has been developed. (Govindarajan, 1968).

As regards processed arecanut, storage for a minimum period is inevitable in the assembling and distributing markets. *Chali* nuts are generally stored in

Table 11.3. *Grade specifications for whole dried arecanut* (kottapak)

Grade designation	Diameter* in inches	Special characteristics			Damaged nuts minimum (%) ***	General characteristics
		Minimum percentage of *topiwalla* nuts**	Colour of pith			
			Copra white minimum (%)	Yellowish brown maximum (%)		
Moti special	1″ and over but not exceeding 1.2″	75	90	Nil	½	The nuts shall be whole, fully husked of light colour and reasonably mature and dry. The nuts shall not be worm eaten or otherwise damaged from outside or inside.
A I	,, ,,	40	60	10	1	
A II	,, ,,	10	10	60	2	
Srivardhan special	0.9″ and over but less than 1″	75	90	Nil	½	
A I	,, ,,	40	60	10	½	
A II	,, ,,	10	10	60	½	
Jamnagar special	0.8″ and over but less than 0.9″	75	90	Nil	½	
A I	,, ,,	40	60	10	½	
A II	,, ,,	10	10	60	½	
Jeeni special	Under 0.8″	75	90	Nil	½	
A I	,,	40	60	10	½	
A II	,,	10	10	60	½	

* To allow for accidental errors in grading 5% of nuts of the next lower or higher grade shall be permitted.

** A nut having a portion of its endocarp adhering to it.

*** Damaged nuts including cracked and broken nuts *(bomda)* pieces, nuts fully husked and those the pith *(bhong)* of which is black or otherwise damaged by moulds, insects etc.

and split arecanuts. A small quantity of sun dried cut arecanut *iylon* was imported from Sri Lanka to meet demand from southern India. The imports were mostly by sea and only a small portion came through land route. The Table 11.5 gives the average quinquennial imports of arecanut into India for the period 1941–'42 to 1971–'72.

Table 11.5. *Imports of arecanut*

Year	Quantity imported in tonnes/year	Value in million rupees
1936–'37 to 1940–'41 (average)	81771	15.7
1941–'42 to 1945–'46 (average)	17542	8.0
1946–'47	36762	30.82
1951–'52	45397	46.60
1956–'57	39879	54.39
1961–'62	10041	4.53
1966–'67	597	0.38
1971–'72	90	0.01

The maximum quantity of imports of 95,300 tonnes was made during 1938–'39 the year preceding the outbreak of Second World War, with an average annual import of 81,771 for the quinquennial period 1936–'37 to 1940–'41. During the years 1941–'42 to 1945–'46 there was a very steep decline in the imports due to war, the entire quantity of imports during this period was from Sri Lanka. After the independence the Government of India, tried to cut down the imports and intensified measures for stepping up domestic production. In 1951, the Government of India fixed a quantitative and monetary ceiling in the volume of imports and also levied a duty on all types of arecanut imported. In spite of these regulatory measures, the import reached a record of 45,397 tonnes in 1951–'52 and caused depression in the local arecanut price. The Government of India, therefore, reduced the period of validity of import licences and also reduced the import qutoa for each licence. From the Third Five Year Plan period onwards, further restrictions were imposed by the Government of India by allowing quota licences for the established importers and at the same time strengthening the development measures for increasing the internal production with the result, the imports were substantially reduced and were practically nil from 1968–'69 onwards (Fig. 11.2).

2. Exports

Though India was importing large quantities of arecanut in the past, it was also exporting small quantities to Burma, South Africa, Kenya, Aden, Fiji Islands etc. for the use of Indian settlers in those countries. The quantity of arecanut exported slightly increased after stopping imports (Table 11.6).

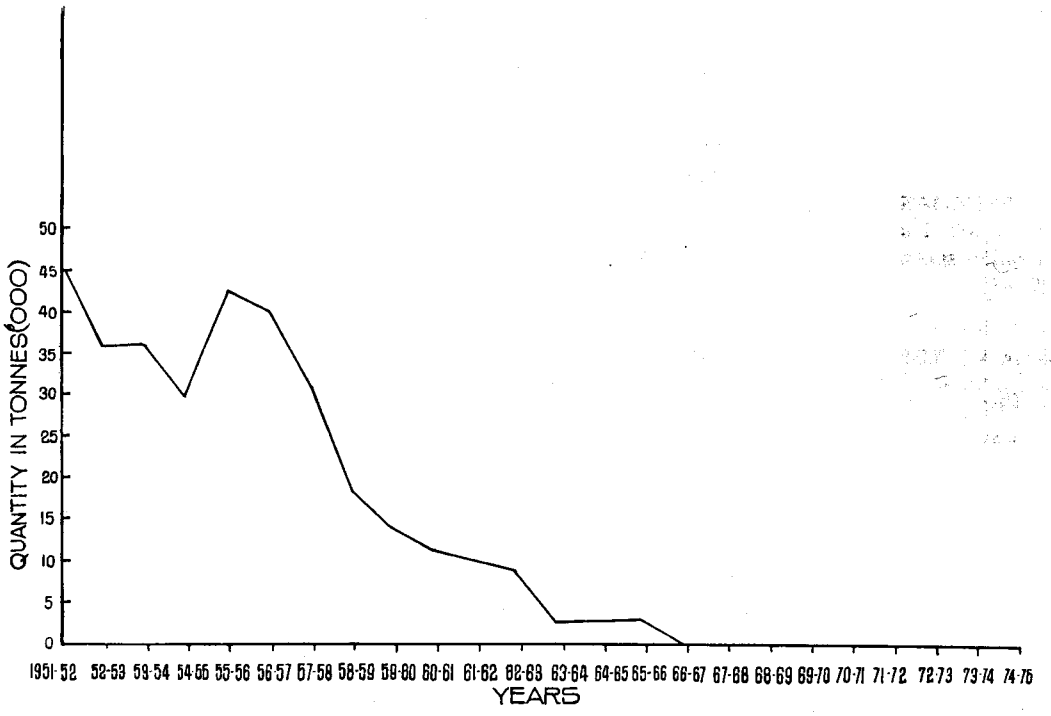

Fig. 11.2 Import of arecanut (1951—'52 onwards)

Table 11.6. *Export of arecanut*

Year	Quantity exported in tonnes/year	Value in million rupees
1936–'37 to 1940–'41 (average)	6344	1.40
1941–'42 to 1945–'46 (average)	869	0.73
1946–'47	675	1.25
1951–'52	170	0.72
1956–'57	227	1.02
1961–'62	123	0.86
1966–'67	219	1.94
1971–'72	292	2.72
1976–'77	603	6.63

The marked rise in the exports during the quinquennial period 1936–'37 to 1940–'41 was due to the separation of Burma from India, as prior to separation, quantities shipped to Burma were not recorded as exports. From the end of the Second World War, Burma got supplies from other producing countries. The exports from India since then were also directed to Singapore, East Africa, Saudi

Arabia, United Kingdom, Nepal etc. The export has shown gradual increase since 1973–'74 (Fig. 11.3) and about 60 per cent of the country's export at present is to Nepal. Arecanut is usually exported in the forms of whole (about 57%), split (about 30%), or ground.

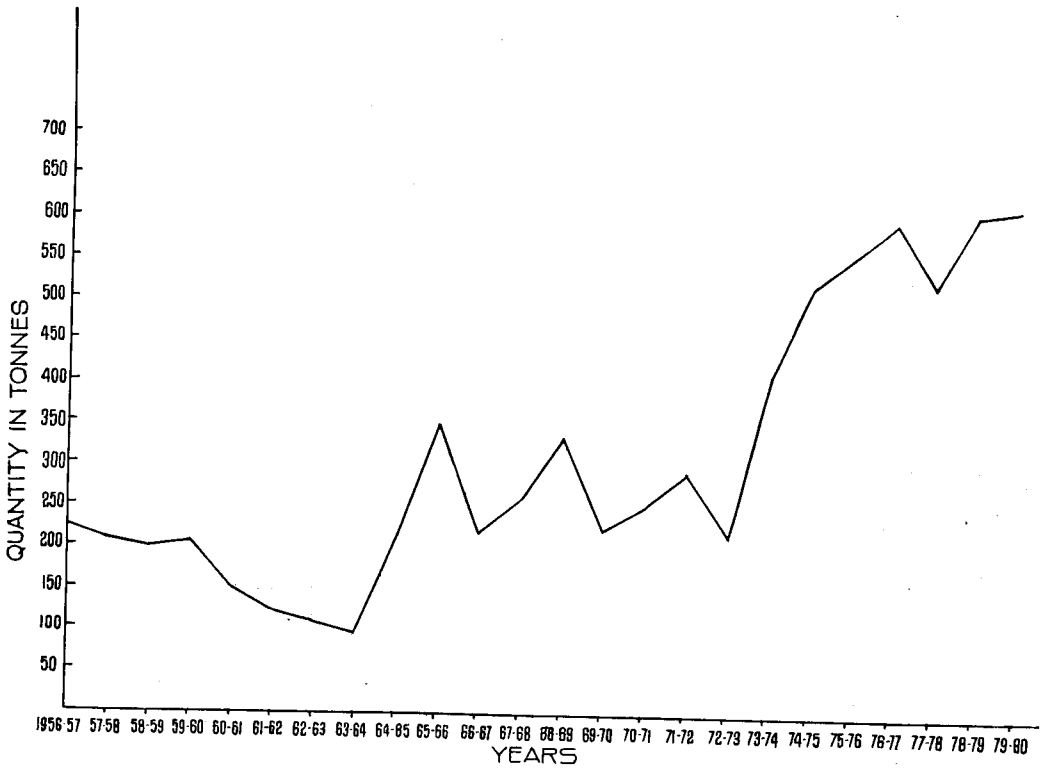

Fig. 11.3 Export of arecanut (1956—'57 to 1979—'80)

Recently *pan masala* containing arecanut (scented *supari*) has been introduced in the export trade and during 1979–'80 the country exported 168 tonnes of scented *supari* valued at Rs. 4.58 million. The importing countries are United Kingdom, United Arab Emirates, Canada, Malaysia, United States of America, Kenya, Fiji Islands and Dubai.

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12

DEVELOPMENT

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The annual production of arecanut in the undivided India was about 1,80,000 tonnes from an area of 2.13 lakh hectares. Nearly 50 per cent of this production was concentrated in the eastern districts of Bengal. There was no systematic cultivation of arecanut and no efforts were made to increase production and productivity of the crop. The developmental assistance rendered by the state governments on arecanut growers was quite inadequate and there was no central agency to look after the problems faced by the cultivators. This necessitated import of large quantities of arecanut into the country annually. With the independence of the country, a large area under arecanut cultivation in Bengal became part of the present Bangladesh. The country was thus left with only 50 per cent of the area and production (Paulose, 1965). The import of arecanut had to be then stepped up to meet the internal demand.

I. Developmental activities

1. *Ad hoc* Arecanut Committee

The Government of India at this juncture taking into consideration the need to improve production and marketing of arecanut in the country, decided to allot an annual grant of Rs. 5 lakhs to the Indian Council of Agricultural Research for the purpose. An *Ad hoc* Arecanut Committee was also set up in 1947 for arranging proper marketing of arecanut, attending to the urgent problems facing the arecanut industry and considering the need for setting up of a standing organisation to foster systematic development and marketing of arecanut (Anonymous, 1948). The *Ad hoc* Committee considered various short term and long term problems confronting the industry and suggested measures to be taken to overcome the same. Organising co-operatives to arrange proper marketing of arecanut, extending financial assistance to small holder farmers, procurement and supply of various inputs required for cultivation were some of the short term measures suggested to improve the situation. The long term measures suggested

by the *Ad hoc* Committee were establishment of research stations for conducting research to find solutions to various field problems as well as for crop improvement in general, setting up of regulated markets at important arecanut growing regions, grading and marketing of arecanut under the Agricultural Produce (Grading and Marketing) Act, improving the quality of the produce by educating the growers in proper processing and drying methods, introduction of scheme for collection of statistics on area and production of arecanut on yearly basis and setting up of a technological laboratory (Anonymous, 1949).

The *Ad hoc* Committee also recommended setting up a permanent Arecanut Committee and approved a scheme for investigating *band* disease of arecanut palm in the erstwhile Bombay state for a period of five years.

2. The Indian Central Arecanut Committee

Based on the recommendation of the *Ad hoc* Arecanut Committee, the Government of India after consultation with the state governments concerned, decided to set up Indian Central Arecanut Committee as a society under the Registration of Societies Act XXI of 1860, as per the resolution adopted on 21st May, 1949. The functions assigned to the Committee were assisting the Government of India in the improvement and development of the production and marketing of arecanut and arecanut products and all matters incidental thereto by (1) assisting or encouraging agricultural, industrial, technological and economical research, (2) undertaking production and distribution of seeds of improved varieties, (3) encouraging and assisting the adoption of improved cultivation and plant protection practices, (4) encouraging the purchase, curing, grading and marketing of arecanut and its products through co-operatives or other agencies (5) giving financial and technical assistance for cultivation, curing, processing, grading and marketing of arecanut and its products, (6) establishing and maintaining research centres and farms, curing centres etc., (7) establishing market intelligence service, (8) carrying out propaganda and publicity in the interest of arecanut industry, (9) recommending the maximum and minimum prices to be fixed for arecanut and controlled purchase and distribution of imported nuts, (10) rendering advice on all matters relating to the development of the industry and (11) advising the Government of India on all matters within the functions of the Committee or performing any other duties assigned by the Government. The developmental activities undertaken by the Indian Central Arecanut Committee are briefly discussed in the following pages.

i. *Survey of waste lands suited for arecanut cultivation in India*

The Committee in 1953 sanctioned a scheme to survey the waste lands fit for arecanut cultivation in the erstwhile states of West Bengal, Assam, Bombay, Mysore and Madras. The survey conducted during 1954 revealed that there were about 9,600 ha of lands fit for taking up arecanut cultivation in north east India, out of which about 2400 ha were in the sub-Himalayan regions of West Bengal and 4000 ha in the upper Assam Valley, 800-1200 ha in Surma Valley and 1200-2000 ha in Khasi and Jaintia Hills. There was also scope for raising arecanut palms in the homesteads.

In south west India, the erstwhile Malabar district was reported to have no waste land but as a mixed garden, it was possible to raise the crop in 36,500 ha of garden land. In the erstwhile South Kanara district there were 2000 ha for fresh arecanut planting. In *Malnad* tracts of Mysore 2300 ha and in Bombay state 850 ha were found suitable for arecanut planting. It was also possible to locate additional area in the forest enclosures. There were also a number of old gardens which required rejuvenation (Anonymous, 1954).

ii. *Establishment of arecanut nurseries*

Before the setting up of the Committee, there was great dearth of quality planting materials in arecanut required to expand area, to replace the old and uneconomic trees and to take up under-planting in the existing gardens. Therefore the first step taken by the Committee towards the development of the crop was establishment of nurseries in the major growing states. In 1951, arecanut nurseries were started in the premises of Agricultural College, Barbhate in Jorhat district of Assam, at Krishnagar in Nadia district of West Bengal and Hutkal near Sirsi in the erstwhile North Kanara district. Nurseries were also established in the Regional Research Stations for arecanut in the erstwhile Bombay, Mysore, Orissa and Madras states (Anonymous, 1952). In 1953, two more additional nurseries were started at Jalpaiguri and Cooch Bihar in West Bengal. These nurseries were continued till 1961 with varying targets for production and distribution of seedlings. From 1953-'54 nursery centres were also operated in north Malabar. During the Second Five Year Plan (1956-'57 - 1960-'61) it was programmed to produce and distribute 92 lakhs of seedlings by establishing 27 nurseries in Kerala, Karnataka, Assam, Orissa and West Bengal. In view of the potentiality for the development of crop in Andhra Pradesh, a nursery programme was started at Sreekakulam in 1956 with a production target of 9 lakhs seedlings over a period of five years (Anonymous, 1958). To encourage area expansion programme in Andhra

Pradesh, a grant-in-aid scheme for establishing demonstration plots in ryots' gardens was implemented for a period of four years from 1958. Another scheme for introduction of arecanut in Adilabad, Karimnagar and Warangal districts was also taken up (Anonymous, 1959). Arecanut nursery programme was started in Andaman and Nicobar Islands in 1957.

In the latter part of the fifties, fresh planting of arecanut was going on in all the potential areas. The farmers were also taking up under-planting and gap filling in the existing gardens. The situation created a heavy demand for seedlings. Therefore during the period between 1957-'58 and 1960-'61 the Committee financed for the establishment of 360 certified nurseries in the states of Kerala, erstwhile Mysore, Assam and West Bengal (Anonymous, 1961). Production and distribution of seedlings was also one of the major programmes in all the six Regional Arecanut Research Stations at Palode and Kannara in Kerala, Hirehalli and Thirthahalli in Karnataka, Mohitnagar in West Bengal and Kahikuchi in Assam and the Central Arecanut Research Station, Vittal.

iii. *Establishment of Arecanut Research Stations*

Indian Central Arecanut Committee sanctioned on a grant-in-aid basis, schemes for establishing Regional Arecanut Research Stations in the erstwhile states of Bombay, Mysore, Travancore-Cochin and Madras. Research Stations were thus established at Ollukkara, Trichur in Travancore-Cochin state and Yedahalli, Thirthahalli in Shimoga district of Mysore state in 1952 (Anonymous, 1953) and at Sakhigopal in Orissa in 1957.

A research station for the investigation of stem breaking disease was set up at Vittal in the erstwhile South Kanara district of Madras state in 1952 and a scheme for investigation of *band* disease was started in the erstwhile Bombay state in 1953 (Anonymous, 1953, 1955). With a view to co-ordinating the activities of the Research Stations established in the arecanut growing states and also to undertake studies on the fundamental problems facing the crop production, the Committee decided in 1953 to establish a Research Station of its own and thus the Central Arecanut Research Station, Vittal came into existence in June, 1955 (Anonymous, 1956). The grower representatives of the Committee had been repeatedly urging for setting up of its own regional centres for speedy implementation of research programmes which were of localised nature. The Committee therefore planned research programmes for each region and initiated work by establishing regional stations. During the years 1958 and 1959 five regional

stations were established by the Committee at Kahikuchi (Assam), Palode and Kannara (Kerala), Kyatasandra (Karnataka) and Mohitnagar (West Bengal) (Anonymous, 1959).

iv. *Disease investigation schemes*

Incidence of some severe diseases on arecanut was brought to the notice of the Committee by the state governments and growers' representatives from time to time. In such instances, on the spot inspection of the affected areas were arranged and the Committee rendered technical and financial assistance to combat the diseases. Some of the important schemes sponsored by the Committee in this connection were (1) investigations on the stem breaking disease in South Kanara district, (2) spraying against yellow leaf disease in Kerala, (3) conducting field trials against *anabe roga* and *hidimundige* in the erstwhile Mysore State, and *band* disease in the erstwhile Bombay State and (4) investigation on new yellow leaf disease in the erstwhile Mysore State. Since the prophylactic measures against fruit rot disease *(mahali)* were known, it was left as the responsibility of state governments to control the disease by arranging sprayings against it.

v. *Simple manurial trials on arecanut in ryots' gardens*

The Committee sanctioned a scheme for conducting simple manurial trials on arecanut in ryots' gardens with the objective of finding out the quantity and form of NPK required for arecanut palm under different agroclimatic conditions. The scheme was operated from 1959–'60 to 1964–'65 and under the programme 200 fertiliser trials were laid out in ryots' gardens in Kerala (100), Karnataka (60), Assam (20) and West Bengal (20). In Kerala the trials were conducted in sub–montane and coastal regions, in Karnataka in coastal sub–montane and plain regions and in Assam and West Bengal the trials were conducted in the plains (Anonymous, 1960).

vi. *Technological research on arecanut*

In order to find out alternative uses for arecanut and its by–products, the Committee sponsored several schemes such as (1) investigation of alkaloids content in various parts of arecanut at Presidency College, Madras, (2) research on properties of arecanut at the Delhi University, (3) utilisation of arecanut for medicinal and other commercial purposes at Calcutta Chemical Co. Ltd., Calcutta, (4) investigation on phenolic constituents and colouring, in arecanut at The Cotton College, Gauhati, (5) research on by–products on arecanut by Kerala and Andhra Universities, (6) investigation on alkaloids in arecanut at Aligarh University and

(7) utilisation of by–products of arecanut by the Central Leather Research Institute, Madras and Forest Research Institute, Dehra Dun (Anonymous, 1952, 1956, 1958).

The Committee set up an Arecanut Technology Unit at the Central Food Technological Research Institute, Mysore in February, 1959 to conduct research on various technological aspects of arecanut (Anonymous, 1959). This Technology Unit was merged with Central Food Technological Research Institute with effect from June, 1962 (Anonymous, 1963).

vii. *Pilot scheme for the study of cost of cultivation of arecanut*

The Committee initiated a scheme to study the cost of cultivation of arecanut during 1959–'60, confined to Shimoga, Chickamagalur and North Kanara districts in Karnataka where pure arecanut plantations were predominant. Under the scheme, basic data regarding various inputs required for arecanut cultivation and also the outputs for a minimum period of two years were collected (Anonymous, 1960; Lakshmanachar, 1964).

viii. *Sample surveys for correct estimation of area and production of arecanut*

A scheme to conduct sample surveys for correct estimation of area and production of arecanut was sponsored by the Committee in Kerala, Karnataka, Assam, Maharashtra, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal during the Second Five Year Plan period (Anonymous, 1959). The scheme started functioning during 1958–'59 in all the states except Orissa and West Bengal where it started in 1959–'60 and 1962–'63 respectively. The survey was discontinued in Andhra Pradesh from 1964–'65 as the area under the crop in the state was negligible. Through the implementation of the scheme, it was possible to estimate the correct area and production of arecanut in India. Ancillary information on nature of holding, healthy and diseased palms, manuring and irrigation, harvesting and disposal, removal and replacement of palms etc. were also covered by the survey (Lakshmanachar, Shamanna and Paulose, 1968).

The area and production estimates of arecanut are now being forecast annually by the Directorate of Economics and Statistics, New Delhi.

ix. *Propaganda and publicity*

The Committee started an extension service scheme for propaganda and control of fruit rot disease in 1950 (Anonymous, 1951).

The committee also began to publish monthly bulletin in English, Malayalam and Kannada from July 1950 containing popular articles on arecanut and also statistics on production, trade, weekly market rates etc. This was changed into *Arecanut and Spices Bulletin* from July 1969 and then as *Indian Cocoa, Arecanut and Spices Journal* from July, 1979. Extension literature on arecanut cultivation, control of pests and diseases, processing etc. were issued from time to time in English, Malayalam, Kannada, Telugu, Bengali, Marati and Tamil.

II. Impact of the developmental activities on production

During the First Five Year Plan period the committee concentrated its efforts on the establishment of arecanut nurseries in potential regions in Assam, West Bengal and North Kerala for production and distribution of quality seedlings which were very much needed at that time. It also initiated work on agricultural research by establishing research stations.

A target of increase in area under the crop by 3,723 ha and an additional production of 18,930 tonnes was aimed at by the end of Second Five Year Plan period. The measure adopted for achieving the target were establishment of new nurseries, laying out of demonstration plots, grant of loans for irrigation units, supply of fertilisers and manures, subsidy for plant protection chemicals and sprayers and publicity and propaganda. By the end of the Plan period, while the target for increase in area was achieved, the production was only 95,500 tonnes as against the 1,01,525 tonnes anticipated.

During the Third Five Year Plan period it was proposed to bring an additional area of 13,514 ha under cultivation in addition to under-plantings in the existing gardens with quality seedlings to increase production by 10,804 tonnes. The development measures consisted of the same as those taken up during the Second Five Year Plan period and it was left to the state governments to undertake such of those measures which were considered feasible and necessary. The programmes implemented by the state governments to achieve the target were production and distribution of seedlings, providing irrigation facilities, giving green manure crops, application of fertilisers, adoption of plant protection measures etc. Though the overall production exceeded the target, in some of the states like Kerala, West Bengal and Maharashtra, the production actually fell short of the initial level of the Plan period. However, the production in other states especially Karnataka, Assam, and Tamil Nadu exceeded the targets and at the end of Third Plan, the total annual arecanut production was 1,19,000 tonnes.

III. Developmental activities of the Indian Arecanut Development Council

In 1965, the Government of India decided to abolish the Indian Central Arecanut Committee and accordingly the Committee was dissolved on 30th September, 1965 and its research activities were taken over by the Indian Council of Agricultural Research with effect from 1st October, 1965. The Department of Agriculture, Government of India took over the development and marketing aspects looked after by the Committee till then. In order to continue the association of various officials and non-officials with the development of arecanut and have the benefit of their advice, the Government of India constituted the Indian Arecanut Development Council in February, 1966 (Anonymous, 1966).

The development programmes were mainly taken up by the Council initially in the states of Kerala, Karnataka, Assam, West Bengal and Tamil Nadu. Apart from the development schemes implemented by the state governments, a centrally sponsored scheme for production and distribution of quality seedlings was initiated at Mahua in Gujarat. During the three years immediately after constituting the Council, the area under arecanut increased from 1,42,100 ha to 1,57,000 ha and the production increased from 1,30,100 tonnes to 1,39,700 tonnes.

The emphasis in the developmental programmes during the Fourth Five Year Plan period was on intensive cultivation of the existing area and discouraging the area expansion under arecanut (Anonymous, 1972). The developmental activities were restricted to the three main arecanut growing states of Kerala, Karnataka and Assam. A centrally sponsored scheme was formulated and implemented during this period to demonstrate the advantages of package of practices in Goa, Assam and Karnataka. A scheme for intensive cultivation of arecanut covering an area of 800 ha every year was also implemented during the period. Against the production target of 1,50,000 tonnes by the end of the Fourth Plan period, the achievement was 1,67,400 tonnes from an area of 1,84,500ha.

No area expansion programme was envisaged in the Fifth Five Year Plan proposals and the target production of 1,60,000 tonnes was to be achieved by increased production from the existing gardens through scientific management.

The production during 1974–'75 to 1976–'77 did not increase to any appreciable extent, probably due to the neglect of the gardens by the growers during the period of the price fall. However, the production picked up momentum in 1977–'78 with 1,75,200 tonnes and thereafter it has been

increasing steadily. Considering the rapid increase in the area and production of arecanut, the Indian Arecanut Development Council has been repeatedly stressing the need for restricting the expansion of area under the crop.

Considering the trend in arecanut production, neither specific production target has been fixed nor developmental schemes formulated during the Sixth Plan Period.

IV. Area, production and productivity of arecanut

The statistics on area and production of arecanut in India for the last 20 years are given in Table 12.1. It could be seen that the area under arecanut had increased from 1,16,830 ha in 1961–'62 to 1,89,200 ha by 1974–'75 and from thereon it came down to 1,70,700 ha in 1976–'77. A steady but slow increase was recorded thereafter and by 1980–'81 the area under arecanut reached 1,84,500 ha showing an increase of 58 per cent within the last two decades. The production of arecanut also showed a steady rise. From 95,170 tonnes in 1961–'62 it reached 1,91,400 tonnes in 1980–'81 registering an increase of 101 per cent during this period (Fig. 12.1). The productivity increased by 27 per cent during the period. The increase in productivity is far higher in Karnataka than the national average (Table 12.2).

Table 12.1. *Area, production and productivity of arecanut in India*

Year	Area ('000 ha.)	Production ('000 tonnes)	Average yield (kg/ha)
1961–'62	116.83	95.17	815
1962–'63	118.28	99.00	837
1963–'64	123.13	98.46	800
1964–'65	125.93	107.51	854
1965–'66	138.10	119.90	868
1966–'67	142.10	130.10	916
1967–'68	147.40	135.40	918
1968–'69	157.00	139.70	890
1969–'70	160.70	137.70	857
1970–'71	167.30	141.00	843
1971–'72	173.80	147.10	846
1972–'73	178.20	147.70	829
1973–'74	184.50	167.40	907
1974–'75	189.20	164.70	871
1975–'76	177.50	160.00	901
1976–'77	170.70	165.10	967
1977–'78	170.80	175.20	1026
1978–'79	179.20	181.90	1015
1979–'80	183.30	189.50	1034
1980–'81	184.50	191.40	1037

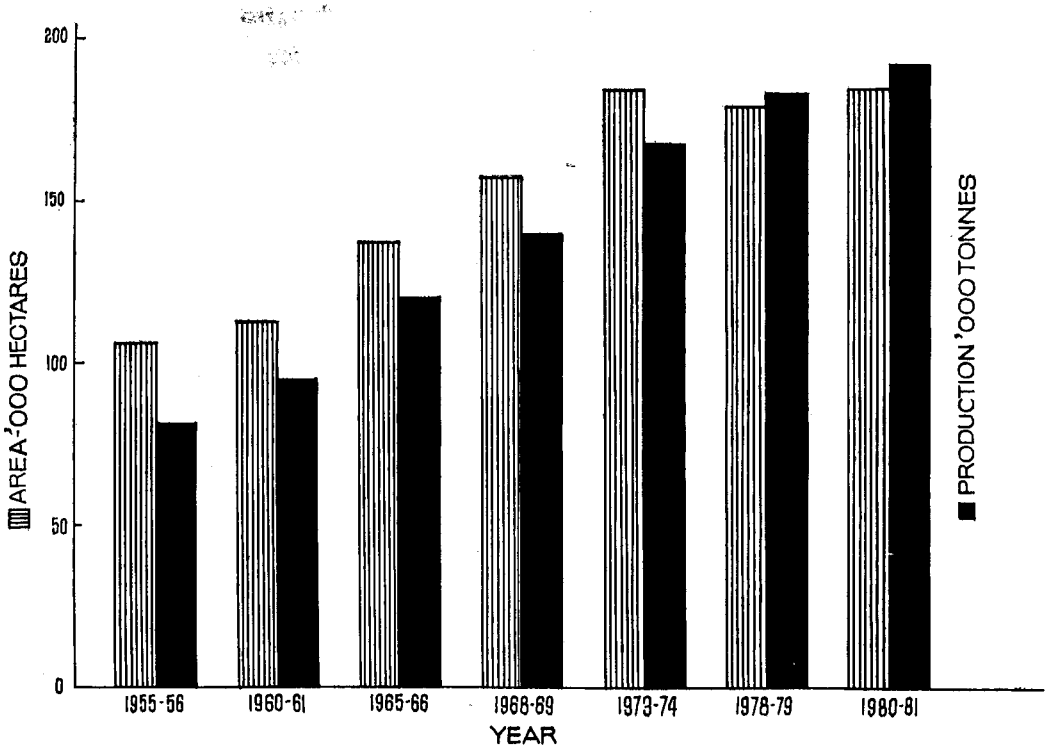

Fig. 12.1 Area and production of arecanut

The distribution of area and production of arecanut in different states and the union territories for the year 1980–'81 shows that Kerala, Karnataka and Assam accounted for 90 per cent of the area under arecanut and 95 per cent of the production. Meghalaya, Tamil Nadu, West Bengal and Maharashtra accounted for only 8.6 per cent of the area and 3.8 per cent of the production in the country (Table 12.3).

1. Area

The area under arecanut in Kerala showed a decreasing trend in recent years. During 1966–'67 the area was 71,200 ha, which increased steadily to 93,000 ha by 1974–'75. Then onwards it was on the decline and came down to 60,900 ha by 1980–'81 (Table 12.2). The yellow leaf disease has partially wiped out the arecanut gardens in the southern part of Kerala and the disease is now rampant in the central and also in some pockets in the northern part of the state. Apart from taking heavy toll of palms every year, the disease rendered arecanut cultivation uneconomical to the farmers due to reduced yield.

Table 12.2. *Area, production and productivity of arecanut in Assam, Karnataka and Kerala during 1966–'67 to 1980–'81*

Year	Assam			Karnataka			Kerala		
	Area ('000 ha)	Production ('000 tonnes)	Yield (kg/ha)	Area ('000 ha)	Production ('000 tonnes)	Yield (kg/ha)	Area ('000 ha)	Production ('000 tonnes)	Yield (kg/ha)
1966–'67	26.2	26.2	1000	34.8	52.7	1514	71.2	44.3	622
1967–'68	26.4	26.4	1000	34.9	54.2	1553	76.0	47.3	622
1968–'69	21.6	23.1	1069	38.1	54.5	1430	81.2	50.6	623
1969–'70	21.8	23.3	1069	38.6	50.7	1313	83.7	51.9	620
1970–'71	23.1	25.1	1086	41.0	50.4	1229	85.8	53.0	618
1971–'72	25.9	29.0	1120	43.2	56.3	1303	86.7	53.4	616
1972–'73	27.1	29.3	1081	45.5	55.7	1224	88.7	54.6	616
1973–'74	30.6	31.2	1020	46.7	72.4	1550	90.7	55.9	616
1974–'75	31.2	32.0	1025	48.2	65.6	1361	93.0	57.2	615
1975–'76	35.0	33.5	957	49.0	69.5	1418	76.6	47.7	623
1976–'77	36.5	38.6	1057	48.9	70.4	1440	68.4	47.8	698
1977–'78	40.4	42.4	1049	50.0	72.2	1444	62.4	51.0	817
1978–'79	46.4	44.5	959	52.3	76.2	1457	62.4	52.2	836
1979–'80	50.8	49.8	980	53.1	77.2	1454	60.9	53.2	874
1980–'81	50.8	49.8	980	54.3	79.2	1459	60.9	53.2	874

The pressure on land in the state and the attraction to grow remunerative cash crops in the place of arecanut are the other reasons for decreasing the area under the crop.

Table 12.3. *Area and production of arecanut in different states during 1980–'81*

State	1980–'81		
	Area ('000 ha)	Production ('000 tonnes)	Yield (kg / ha)
Andhra Pradesh	0.2	0.2	1000
Assam	50.8	49.8	980
Karnataka	54.3	79.2	1459
Kerala	60.9	53.2	874
Maharashtra	2.1	2.5	1190
Meghalaya	6.5	0.9	138
Tamil Nadu	4.3	3.0	698
Tripura	0.6	0.4	667
West Bengal	3.1	0.8	258
Goa	1.4	1.3	928
Mizoram	0.3	0.1	333
Total	184.5	191.4	

The area under arecanut in Karnataka increased steadily, though the rate of growth was very slow. From 34,800 ha in 1966–'67 it increased to 54,300 ha (56%) by 1980–'81 (Table 12.2). Availability of suitable land for extending cultivation and other infra–structure encouraged the farmers to take up arecanut cultivation. Arecanut cultivation in Karnataka is looked upon as a profitable venture. Scientific cultivation adopted in most of the regions and a well organised co-operative marketing system seems to have contributed to the steady increase in area in the state.

In Assam the area under arecanut increased from 26,200 ha to 50,800 ha during the period from 1966–'67 to 1980–'81 registering 94 per cent rise. Availability of suitable land and the steady demand for the produce in north eastern region encouraged taking up of arecanut cultivation.

2. Production and productivity

In Kerala though there was a reduction in area, the production increased from 44,300 tonnes in 1966–'67 to 53,200 tonnes in 1980–'81. This is due to the increased productivity from 622 kg per ha to 874 kg per ha (Table 12.2).

In Karnataka, the increase in production was 26,500 tonnes (50.3 per cent) between 1966–'67 and 1980–'81 and increase in area was mostly responsible for the rise in production. Average yield per hectare in 1966–'67 was 1,514 kg which declined to 1,224 kg in 1972–'73. Thereafter the productivity started raising and reached 1,459 kg in 1980–'81 (Table 12.2). Occasional fall in productivity was due to the severe incidence of *mahali* disease.

In the case of Assam, when the area under arecanut increased 94 per cent during the 15 year period from 1966–'67, the production also showed an increase of 90 per cent. The productivity which was 1000 kg per ha, went up to 1120 kg by 1971–'72. Thereafter it decreased and came down to 980 kg per ha by 1980–81. According to Murthy (1968), lack of regular under–planting of palms and indiscriminate planting of other crops had resulted in over crowding and poor yields in the arecanut gardens located in hill slopes and low lying areas in Assam. Inadequate manuring, lack of drainage in low lying areas and rainfed nature of the crop were the other contributing factors to the decrease in productivity.

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FUTURE OF ARECANUT

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The future of arecanut in this country is being debated in recent years, because of more than 100 per cent increase in production achieved within the last two decades, the reported dwindling chewing habit of the present generation, lack of export potential and economically viable alternative technology to utilise the nut and its by-products. The sudden price fall in the wake of a spurt in production in the beginning of the last decade also contributed in predicting a bleak future for arecanut. However, subsequent trend in demand and supply, and very remunerative price prevailing at present, have not substantiated this apprehension.

I. Production trend

An analysis of the trend of increase in area, production and productivity of arecanut in the country, starting from 1961–'62 shows that in the sixties the area under the crop increased at the rate of 4.3 per cent per annum, the production at 4.8 per cent and productivity at 0.34 per cent. In the next decade (1971–'72 to 1980–'81) the area increased at the rate of 2.0 per cent per annum, whereas production increased at the rate of 3.5 per cent. The productivity increased during the decade by 23 per cent compared to 3.4 per cent in the previous decade, and this could be attributed to the impact of the results of research initiated towards the end of fifties. The increase in production by more than 100 per cent during the last twenty years has however been partly due to the increase in area to the extent of 57.9 per cent (see Table 12.1).

II. Yield gap analysis

In the absence of information on photosynthetic efficiency, total dry matter production and harvest index, any prediction on yield potential in arecanut will be speculative. The difference between the potential and actual yield is generally

designated as *yield gap*. An average yield of about 8 kg of ripe nuts per palm per year has been obtained by several progressive farmers in Dakshina Kannada and Uttara Kannada districts of Karnataka and this can be taken as a standard for the immediately realisable yield. The present average yield of 1,037 kg of *chali* per ha for the country, works out to about 2.5 kg of ripe nuts per palm per year and this represents only about 32 per cent of the realisable yield. However, the yield potential is much more than this since an average yield of about 14.5 kg of ripe nuts per palm per year has been obtained from two cultivars (VTL–11 and VTL–17) for a period of nine years at CPCRI Regional Station, Vittal (see Table 3.11) and this can be regarded as the realisable yield goal. The best ever recorded yield in arecanut is 30 kg per palm per year (Anonymous, 1972) and based on this, the yield gap ratio at present is

$$\frac{\text{Record yield}}{\text{Average yield}} = \frac{30.0}{2.5} = 12.$$

The gap between the highest realisable yield (30.0 kg) and the best average yield so far achieved at the research station (14.5 kg) can be termed as the *research gap*. This gap can be filled up only through concerted inter-disciplinary research programmes. The difference between the best yield obtained at the research station (14.5 kg) and the yield obtained by the progressive farmer (8 kg) can be referred as the *development cum extension gap*. To bridge this gap, developmental efforts are called for to produce adequate quantities of planting material in improved cultivars such as *Mangala*, VTL–11 and VTL–17, optimum fertiliser application based on soil fertility factors, timely irrigation in summer months, plant protection measures against *mahali* disease and mites and above all technical support and guidance to the farming community. The gap between the average yield in the country (2.5 kg) and average yield obtained by the farmer (8.0 kg) can be referred as *extension gap*, and to fill this gap, it is required to transfer the established arecanut management technology to farmers through intensive efforts of extension agencies.

In the light of the above analysis it would appear that by bridging the *extension gap* alone, almost three-fold increase in production of arecanut could be achieved in this country and by bridging the *development cum extension gap* the production could be increased by six times from the existing area (Fig. 13.1). This is a good pointer for taking up concentrated developmental efforts in the more favourable areas of arecanut cultivation through, investment oriented programme with all the input components such as high yielding varieties, optimum fertiliser

application, irrigation, plant protection measures etc. If such programmes could be implemented successfully, there would be considerable scope for reducing the existing area under arecanut.

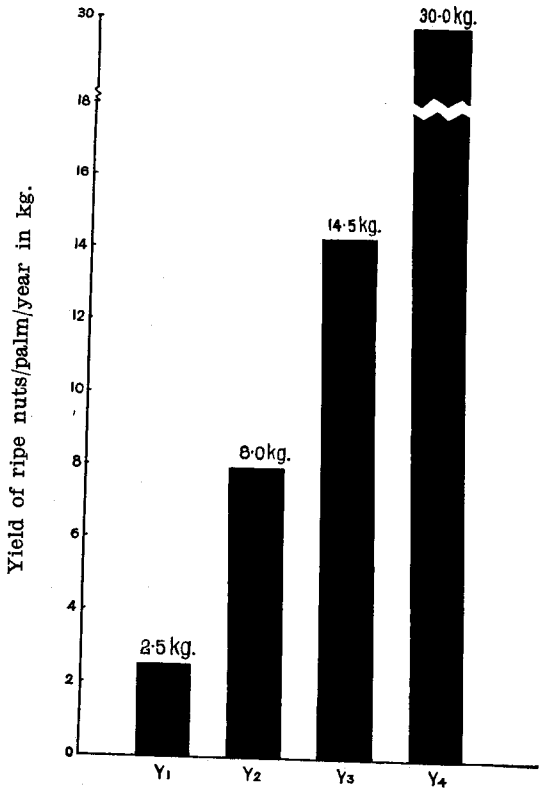

Fig. 13.1 Yield gaps in arecanut. $Y_2—Y_1$ = *Extension gap;* $Y_3—Y_2$ = *Development* cum *extension gap;* $Y_4—Y_3$ = *Research gap*

The reduction in area from 1,89,200 ha during 1974–'75 to 1,70,000 ha during 1977–'78 without any appreciable reduction in production (see Table 12.1), indicates that it would be practically possible to bring down the area under the crop considerably and divert the land to some other commercial crops. It is reported that in certain parts of Kerala, in recent years, the yellow leaf disease affected arecanut garden have been replanted with rubber.

The National Commission on Agriculture has projected the requirement of arecanut in 2000 A.D. as about 1,90,000 tonnes and production at the yield level of 1600 kg per ha at about 2,70,800 tonnes from the existing area of 1,74,000 ha.

From the surplus of about 80,000 tonnes, which partly will go for other uses, it has been indicated by the Commission that a reduction in area under the crop may be thought of at a later stage (Anonymous, 1976). However it is interesting to note that even the present production of 1,91,000 tonnes is used within the country without any visible symptom on price structure of the commodity. This shows that our internal capacity to utilise the increased production is much more than the estimated figures. Thus well planned developmental and extension efforts could be rewarding in this crop to increase productivity on one side and reduce the area on the other.

III. Suggested future lines of work

From the foregoing discussion, it would appear that the future strategy for research and development should be to maximise production and productivity of arecanut plantations, find solutions for the more important maladies affecting the crop and ensure the market stability for the commodity. The National Commission on Agriculture has also opined that the existing research and developmental set up in the states and the Centre are sufficient for this crop (Anonymous, 1976). The future research and developmental efforts therefore should be directed to achieve these specific objectives.

Out of more than 40 species described in the genus *Areca,* so far only about half a dozen species are available in the germplasm, being maintained at CPCRI Regional Station, Vittal. Hence, it is necessary to assemble the remaining species and cultivars by a systematic collection programme not only from within the country but also probably from the centres of origin. Establishment of a gene pool containing species and types of genus *Areca* would open new possibilities of incorporating characteristics not available in the existing cultivars.

The varietal evaluation for over 15 years based on multi-location trials has indicated that besides *Mangala,* equally if not better yield potential cultivars such as 'Thirthahalli' (Anonymous, 1974), 'Andamans' (Anonymous, 1972) VTL-11 and VTL-17 (see Table 3.11) exist in the available germplasm collection. It is expected that atleast one or two selections among these will be released for cultivation in the near future. Varietal evaluation and release programme should be continued for ensuring a broad genetic base. The potential of hybrids in disease resistance has been indicated by the comparative tolerance of Dwarf × *Mangala* hybrids to yellow leaf disease. Therefore, selection and resistance breeding to yellow leaf disease should receive high priority.

The future of arecanut as a plantation crop has to be centering on farming system in which arecanut is a base crop with cocoa, pepper, cinnamon, coffee etc. as mixed crops or tapioca, sweet potato etc. as intercrops. Practically very little knowledge exists at present regarding the cultural and manurial requirements of arecanut in the mixed or intercropping system. While the possibilities of increasing the production from unit area and income in such a cropping system has been indicated (see Tables 5.6 and 5.7), optimum input requirements are yet to be worked out. It is also necessary to select varieties and cultivars of not only arecanut but also the other components of the mixed and intercropping system, so that a most profitable and compatible crop combination could be advocated to the farmers.

In the mixed cropping, ecosystem is entirely different from the mono cropping system and basic ecology of the area is likely to change resulting in modification in the behaviour of insect pests. These alongwith problem of out-break of new pests would warrant continued pest research in arecanut.

In the field of disease control, the most serious threat to the crop at present is yellow leaf disease, the etiology of which is yet to be clearly understood. The etiology of the disease is as baffling to the scientists at present as the root (wilt) disease of coconut. While the problem is being tackled from management, nutritional and pathological angle as well as by resorting to resistance breeding, a break-through is yet to be achieved. Though various pathogens such as fungi, nematodes, bacteria and mycoplasma like organisms have been implicated in the etiology, the exact role of any one of these organisms is yet to be substantiated. Concerted inter-disciplinary approach is required to combat this debilitating disease.

Though the causative organism of *mahali* has been identified and remedial measures are available, since the disease makes its appearance during the rainy season, effective control measures at the time become rather difficult. To overcome this, the necessity for collecting epidemiological data for an effective disease forecasting system needs attention.

Since the bacterial leaf stripe is at present restricted to certain parts of *Maidan* area of Karnataka, strict regional quarantine measures are to be imposed to check the disease spread to other areas.

IV. Developing arecanut based industry

The future of arecanut and arecanut based industry depends on the extent to which an economically feasible alternative use for the different constituents of the nut could be developed early. The need for further investigation in the pharmacognosical aspects of arecanut is relevant in the present time when there is renewed interest in utilising the natural products in medicine.

Defatted arecanut appears to be non–irritant to mucus membrane of mouth. Constant irritation of mucus membrane generally initiates cancer lesion, hence further work for the identification of the irritating principle is needed. This will also throw some light on the relationship or association between oral cancer and arecanut (Balendra, 1949).

The possibilities of using various constituents of nuts such as fat and polyphenol fractions including as a colouring matter for food and as an ingredient for tooth paste and chewing gum could be studied in greater depth. Probably what is feasible would be an integrated processing unit where in the various component constituents of nut could be progressively extracted and utilised to have an economically feasible and viable arecanut based industry.

The most promising technology developed so far has been the utilisation of arecanut leaf sheath for preparing plyboards, decorative panels, packing cases etc. It would not be difficult to start small scale industry at the village level to produce flat sheets out of leaf sheaths by setting up a hot platten press.

In the field of arecanut marketing, though the co–operative institutions such as CAMPCO have played an important decisive role in the recent years in the states of Karnataka and Kerala, there is urgent need for streamlining the market system assuring a reasonable return of consumers' price to the arecanut growers. Establishment of regulated markets in states like Meghalaya, Mizoram and Tripura could bring an orderly marketing system where at present none exists.

Though arecanut production and related activities are reckoned as a major industry, it is a fact that no efforts at any time have been made for popularising use of this commodity. With its wide acceptability as a masticatory, particularly as processed end–products such as scented *supari,* efforts to popularise arecanut could substantially enhance its internal consumption as well as export potential. Chewing of processed arecanut by a large section of people of Indian origin· settled in other countries, coupled with adequately well planned sales promotion

efforts could considerably increase the demand for arecanut. In view of the numerous uses for which arecanut has been put to, as described in this monograph, besides its main function as a masticatory, it is to be assumed that it will have an impact in future also, possibly through developing a suitable alternative technology for its utilisation.

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